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American Institute of Electrical Engineers

COMING MEETINGS

Midwinter Convention, Philadelphia, Pa., February 4-8

Spring Convention, Birmingham, Alabama, April 7-11

Annual Convention, Edgewater Beach, Chicago, Ill., June 23-27

Pacific Coast Convention, Pasadena, Cal., October

MEETINGS OF OTHER SOCIETIES

American Engineering Council (F. A. E. S.) Washington, D. C., January 10-11

N. E. L. A., Technical National Section, Birmingham, Ala., January 28-February 1

American Society of Civil Engineers, Annual Meeting, New York, N. Y., January 16-18

JOURNAL

OF THE

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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Communication Engineering

So far as the tasks of the inventor and the engineer in improving systems of electric transmission of intelligence are concerned there is a difference in the problems of the "wire" and the "wireless" engineer.

In telegraphy and telephony by wire the betterments over a period of twenty-five years have resulted mainly from improvements made in the media extending between the terminal instruments—the line and the cable. The telephone transmitter and receiver, for instance, are today almost identical with what these devices were forty years ago. The quality of transmission thirty-five years ago was as good as it is today. The improvement has been that the distance has increased from say one hundred miles to two thousand miles.

The telegraph has improved in dependability and speed, also mainly as a result of improved line construction and maintenance, increased insulation, and improvements in aerial and underground cables. The Morse Key, the relay, the sounder, and the apparatus of Morse multiplex working have changed in construction; not in principle. True, the development and extension of printing telegraph systems stands as an advance in terminal apparatus, but much of the success of present day printing telegraph systems is due to betterments in line circuit conditions over those which were available to early printing systems.

It would appear therefore that aside from ingenious mechanical refinements and extensions of terminal plant and organization to care for the growth of telegraph and telephone traffic, that the engineering gains which account for improved transmission have been mainly those involving "line" conditions.

In radio telegraphy and radio telephony, the inventor and the engineer in order to produce systems which will be improvements upon present systems have only the field of terminal apparatus in which to work. The medium connecting transmitting and receiving installations (aside from guided carrier systems) is not likely to be subject to treatment of a sort that would affect the grade of transmission through it of radio signals.

The radio engineer has no choice but to aim to develop terminal apparatus which will render the grade of transmission desired when the intervening medium is in a condition least favorable to the maintenance of dependable operation.

Radio terminal apparatus might be designed to have what could be termed a Factor of Surplus. Transmitters of given design and given power input embodying this factor might be expected to provide satisfactory service throughout the occasional periods when the least favorable media conditions prevail. Good design might provide that when conditions are favorable or normal the strain upon the Factor of Surplus could be reduced permitting immediate economy in operating costs.

The fact that the problems of radio are problems of terminal apparatus only, accounts for the pronounced alterations noticeable, after the passing of a few years, not only in the design but in the principle of radio equipment.

A Sociologic Aspect of Superpower

The problem of the crowded city has been the topic of civic, social and political debate these many years; the solution seems ever further away. It is true that tremendous improvements have been suggested, and many have been made—all tending towards relieving the congestion by speeding up movement—of human freight, of goods, of transport generally. But these are palliatives only—they rather increase than alleviate the evil, for they make it still easier for vast congregations to grow.

The city arose from the development of the steam engine, which made available hitherto undreamt-of power at one place. Does the solution lie with electricity, which can render its services broadspread through the land? The power transmission network is a new factor in social and economic life—a factor which will almost certainly favor decentralization of industry. Already new factories tend to establish themselves in regions where land is cheap, transportation uncongested, and space for expansion abundant. When power is available everywhere in the great industrial countries of the world, at rates which place the small town at no disadvantage towards the city, the tendency towards decentralization will be more and more pronounced. There will be no inherent advantage in establishing industries where other industries already congest, no advantage in bringing the raw material to

the power at great expense, no need to ship the finished product over clogged arteries of transport, when power is more easily conveyed than the materials upon which it is destined to act. It would seem likely that with the dawn of the electric age will come decentralization, with proximity to raw materials, less pressure of transport, new access to markets, small rents and taxes, and many other advantages, social and economical, just as with the steam engine came all the evils of the crowded city. —*Beama*

Engineering Nomenclature

IN the December issue of the JOURNAL in discussing the paper by Arnold and Espenchied on "Trans-atlantic Radio Telephony," W. V. Powell points to certain variations in terms applied to what appear to be identical factors. Mr. Powell calls attention to a situation which in recent months has been widely commented upon by engineers—that the development of Standardized Nomenclature should follow more closely the developments in laboratories.

It is perhaps true that only engineers who have served on Standardized Committees have a knowledge of the difficulties of standardization.

There is no task assigned for committee action which consumes more time in producing useful quantities than that of Terminology. A committee charged with the duty of wording definitions of terms more or less widely used in engineering literature is of necessity made up of engineers who know their science intimately and who in addition are gifted as writers of correct and clear English.

Men so qualified are not numerous, and from the number available only a few are situated so that they can contribute the time necessary to accomplish appreciable results in this work.

When it is realized that ten or twelve properly qualified engineers may devote an entire evening to the construction of two or three definitions, the magnitude of the undertaking may be understood.

In the past individual engineers, serving on Standardization Committees, have given generously of their time to the work of framing the definitions now available in published form, and there could not be a more striking instance of the loyalty of these engineers to the Institute, its purposes and activities than that evidenced by the attendance at committee meetings—perhaps weekly throughout a year—while a Standardization Report is in course of preparation.

The views expressed by Mr. Powell in his discussion suggest the next step in standardizing terms: That of giving publicity to definitions as they are approved without waiting until the work for the year is completed and ready for publication as a whole.

Lighting Increases Coal Production

In an editorial in *The Illuminating Engineer*, official organ of the Illuminating Engineering Society founded in London in 1909, Leon Gaster calls attention to an investigation by Messrs. Farmer, Adams, and Stephenson on the effect of more powerful illumination on production in coal mines. Mr. Gaster points out that while a great deal of attention has been given to lighting conditions in coal mines from the standpoint of health of the miners, little has been done to determine the effect of illumination on production.

In the test referred to, volunteers agreed to use special lighting equipment which weighed approximately five times as much as the lamps they ordinarily carried. This special equipment furnished about six times as much light as the men were accustomed to work under. In spite of the handicap of extra weight, the eight weeks' test revealed an increase in production of 14½ per cent.

The average output of coal per man per shift before use of big lamps was 2.47 tons; the average output of coal per man per shift during use of big lamps was 2.83 tons; the increase being 0.36 ton, or 14.6 per cent.

While the adoption of higher levels of illumination in coal mines is not the simple matter it is in most industries, due to the fact that the miner carries not only the lighting equipment but the energy supply as well, nevertheless it appears that the effect of better lighting on both the eye health and the productive capacity of the miner justifies further investigation of the possibility of providing more illumination even at some increase in weight of equipment. It is significant that in the tests reported the miners volunteered to carry outfits weighing five times as much as their ordinary lamps.

To the advocate of better lighting these tests are important as furnishing one more example of an industry in which production has responded to improvement in illumination.

Notes and Comments

In order to afford a prominent place in the JOURNAL for important announcements, news notes of special interest or editorial comments the first two pages of each number beginning with this issue of the JOURNAL will be held open for this purpose. It is believed that this provision will be welcomed by Institute officers, committee members and others active in Institute work who from time to time may have brief messages of interest or importance to impart to our membership. Some of the items appearing on these pages this month are from members of our technical committees and further contributions along the lines indicated are invited.

Superpower Transmission

Economies and Limitations of the Transmission System of Extraordinary Length

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Review of the Subject.—*This paper is a study of the transmission of very large blocks of power for extraordinary distances and has for its purpose the bringing out of the major operating characteristics of such a system, the characteristics which it possesses which are different from those of shorter transmissions and the duties imposed upon generators, transformers, synchronous condensers, switches, etc., primarily as affecting their design. The paper defines a superpower transmission line as a line of great length in which the charging kilovolt-amperes per mile of length is of the same order of magnitude as the reactive kilovolt-amperes developed by the full-load line current passing through the reactance of the line and in which the resistance is small relative to the reactance.*

Such a line is adapted for economical transmission only for a fairly definite amount of load and any great increase or decrease below this point leads to poor economy or unstability. Since, however, the load appropriate to a given line depends upon the voltage, an appropriate line can be laid out for any reasonable amount of power to be transmitted.

In order to secure a definite set of conditions to serve as a specification for determining the performance of generators, transformers etc., all applying consistently to the same system, a typical hypothethical transmission has been assumed, namely, a delivery of 400,000 kw. over a distance of 500 miles over four circuits 220,000-volt at each end.

The characteristics of this line are worked out showing the efficiency, condenser capacity required, data on circuit breaker arrangements, protective relays connection to receiving network, provision for spare parts, switching of units and ratings of various apparatus.

It is shown that such a system is very sensitive to the receiving end voltage; when this voltage drops there will be a tendency for the generators to run away if the system is not properly laid out.

In addition a discussion is given of the effects of various prescribed values for the terminal voltage between 220,000 and 245,000 to show the effect of increasing the voltage 10 per cent, of maintaining the generating end 10 per cent higher than the receiving end and also of stabilizing the middle point with synchronous condensers.

The typical hypothetical case chosen shows one layout, it being recognized that other layouts may be chosen. This particular layout is operated without any high-tension switching of live lines. The layout is intended to relieve the duty on circuit breakers and as a matter of fact no breaker can be called upon to interrupt a short circuit of more than ¾ of a million kilovolt-amperes; this is a very favorable condition and is secured without materially limiting the equalization of the load. The layout connects with the assumed distribution net at a considerable number of points and no large portion of the total delivered power can be concentrated at any one point; this serves to secure a very intimate connection between the network and the transmission, and at the same time prevents any one breakdown, however, complete, from materially disturbing the major portion of the transmission system.

Introductory

THE art of electric power transmission is just entering upon another stage of development, and this a most important one. The period characterized by the general adoption of the 100,000-volt line has been most fruitful. The coming period with lines of voltages in the neighborhood of 225,000 volts and of very great length will be marked by important changes from the old apparatus and the old practise. Considering electrical problems, the 100,000-volt line, to the usual designer, is a problem in drop, to keep the voltage at the substation within reasonable range of the generator voltage with varying load, to secure a good efficiency, and to watch the charging current to see that the light load conditions do not cause an unduly high potential or overload a generator. There is also the problem of insulation, but this is constituted largely of selecting a good make of insulator and watching the manufacturer, also the maintenance of the insulators in good condition during operation.

For the superline of the coming period, the problem of the designer is much more complex. The matter of power factor instead of being merely one of the underlying factors in drop calculations, becomes the all-important feature of the line, serving as the only feasible means of controlling voltage and efficiency. It must be completely under control of the operator. Instead of establishing the voltage at one end of the line as a means of controlling the voltage at the other end, the voltage in the superline must be controlled at both ends and care taken to keep track of the voltage at the center of the line to see that it does not rise too high. Instead of adding reactance to keep down the heavy current in short circuits, as in the 100,000-volt system, the designer will find that with the superline the short-circuit current may not greatly exceed full-load current and that the securing of enough current over the line to insure the holding of the machines on the two ends of the line in synchronism at times of disturbance becomes a serious problem. Other features bring forward novel conditions.

It is the purpose of this paper to discuss the nature of the super transmission system, bringing out some of the peculiarities characteristic of it and to offer some numerical data to give some measures of its economies and limitations. In order to give concreteness to the discussion, a typical but hypothetical example is chosen and the layout worked out in enough detail to develop the novel problems involved and suggest solutions. A sufficient number of calculations are made to determine

To be presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

the performance of the system under all conditions normal and abnormal.

Capacity

Unlike the ordinary 100,000-volt transmission line, chosen for efficiency or regulation, the superline has a substantially definite kilowatt capacity which cannot be practically exceeded. In this use of the term, a "Superline" is to be taken as a long line in which the kilovolt-ampere of charging current is numerically of the same order as the kilovolt-ampere developed by the load current in the reactance of the line, and in which the resistance is small in comparison with the reactance.

The dominating role of this relationship of charging kilovolt-ampere to line reactance kilovolt-ampere, set forth in a paper of my own in 1909, has been well expounded by Mr. Harold Goodwin, Jr.[1]

Very briefly its significance may be stated as follows: Since the resistance component of line drop is proportional only to the resistance, which can be made as small as desired, while the reactive component is proportional to the reactance of the line, which is substantially fixed beyond the control of the designer, the kilowatt capacity of a line cannot be made to exceed the fixed limitation imposed by the reactance unless some additional factor be introduced. The reactance considered alone would greatly reduce the capacity of superlines below that actually available. It would largely eliminate any advantage in the reduction of resistance beyond a certain point.

This situation may be avoided, however, by proper control of the line charging current; which fact may be explained as follows: For any definite section of line the charging current represents a certain kilovolt-ampere value, having a phase 90 deg. in advance of the voltage ($\frac{1}{2}\, C\, V^2$). Similarly in that section of line there is a kilovolt-ampere value due to the current passing through the line reactance ($\frac{1}{2}\, I^2\, X$) which is 90 deg. behind the line current in phase. If now the power factor is unity and the current and voltage are in phase with each other, the phases of these two kilovolt-ampere values will be exactly opposite and if equal they will neutralize each other as far as the rest of the system is concerned. This will leave the resistance as the only quantity causing line drop. That is, by the proper correlating of power factor, line voltage, and load current, the voltage drop may be made to be that due to resistance only. To put it another way. In an excited open-circuited high-voltage line the charging current causes a rise of potential along the line toward the open end. On the other hand, in a loaded line without charging current, the line reactance causes a drop in voltage toward the loaded end. If these two tendencies be made numerically equal by properly choosing voltage and load and be made opposite by establishing unity power factor, the tendency to rise and the tendency to drop will neutralize, leaving the resistance to determine the actual line drop.

It goes without saying that in an actual line, some departure must be made from these ideal conditions, and it is the function of the designer of the superpower line to so control these departures as to secure the best compromise between efficiency, regulation, operating quality, etc. and cost.

For carrying large loads obviously a high voltage is necessary, but for any given load a particular voltage is most suitable. In this particular relation frequency plays little part, since the neutralization described above is not affected by change of frequency. Neither does the length enter as a factor theoretically, except to the extent that the consequences of a departure from ideal conditions will have a smaller effect with a short line and for the effect of ohmic resistance. Similarly frequency is of great importance when the ideal neutralization is not secured, as occurs with light load short circuits, etc.

Having chosen the load to be carried and the proper voltage, or having chosen the voltage and the proper load corresponding, the resistance can be chosen to determine the energy loss or efficiency. The designer does not, however, have a free hand to vary the resistance, as it is the resistance that is one of the potent factors tending to upset the balance of reactance and capacity, and is thus closely linked with power factor. The formula given by Goodwin, viz., kv-a. = $e^2/.04$ Where "e" is the line kilovolts gives a good idea of the equalizing capacity corresponding to various voltages.

In my paper of 1909 above referred to, I have suggested certain methods of increasing the load capacity of a super line without increasing the voltage, such as using divided conductors. While I see no reason why this method is not perfectly feasible, so far no occasion seems to have arisen in which there is not some other method less novel which would serve to secure the necessary capacity. This method is not a part of the subject matter of the present paper and will not be further touched on.

Regulation

In the superpower line, voltage regulation is naturally a most important function and fortunately, thanks to the competent means available, may be very satisfactorily controlled.

In the first place it will be necessary to have control of the voltage at both ends of the line independently. Since synchronous type apparatus is used on both ends and since the voltage drop is extremely sensitive to power factor, no single setting of the field current on the synchronous machines on either end of the line would serve to secure satisfactory voltage at that point.

While not theoretically necessary, usually the most satisfactory regime for regulation will be to maintain voltage constant automatically at each end at whatever voltage may be most suitable at that end. The

1. Qualitative Analysis of Transmission Lines, A. I. E. E. Journal, January 1923.

voltage, if necessary, may even be somewhat higher at the receiving end without serious additional expense. To arrive at the nature of voltage regulation in a superline, we may assume that the line is carrying full load with the capacity kilovolt-amperes and the reactance kilovolt-amperes equalized. If now a small leading current be made to flow from the generating to the receiving end, this leading current passing through the line reactance will cause a tendency for a rise in potential toward the receiving end. By choosing the amount of this leading current the amount of rise can be controlled. The effect of the resistance is of course, such as to cause a drop due to this leading current, but since in the superline the reactance is much greater than the resistance, and since the resistance component of the leading current voltage effect will be out of phase with the leading current, it will be substantially negligible; conversely with a lagging current.

To put this in another way. If we establish a voltage at each end of the line corresponding to the condition corresponding to the leading current just described, the line currents must flow as described to produce these voltages. Since any constant potential synchronous machine has a definite voltage and will supply, within its capacity, any current to its circuit required to maintain its voltage, such machines are entirely suitable for superpower line regulation especially in connection with field regulators.

Connected to the receiving end of such a line, a synchronous machine will tend to supply whatever current the transmission line takes at that voltage and at the same time to supply the load current required by the system connected to the line. The synchronous condenser actually takes, however, only the difference between these currents, which may be large or small and positive or negative as the case may be. In case the power factor of the load is low and the power factor required by the line close to unity, there will be a large out-of-phase kilovolt-amperes to be supplied by the synchronous machine at the receiving end and this is the most salient fact about the use of the synchronous machines, usually synchronous condensers.

Thus it is clear that any fixed voltage at either end may be easily maintained and for any load up to full load if proper synchronous condensers are available. This voltage will be held fixed by automatic regulators.

Equation of Typical Line

To illustrate numerically where these fundamental principals lead, I have assumed a superline of rather an ambitious capacity, but still an entirely feasible one for our present day knowledge, and have made the necessary calculations.

This line is 500 miles long, this being taken as an exceptionally long line and is insulated for 250,000 volts, 60 cycles. Its conductor has an outside diameter of $1\,{}^{3}/_{32}$ in. and its resistance is 0.015 ohms per thousand feet of cable, or the equivalent of 700,000 cm. The mean conductor spacing is 15.8 feet[2].

Performance of Line

Fig. 1 shows the efficiencies of this line for loads from about 10,000 kw. delivered up to 150,000 kw. on the following four assumptions as to terminal voltage conditions:

(A) that a voltage of 220,000 is maintained at each end.

(B) that a voltage of 220,000 is maintained at each end and that 220,000 volts is also maintained at the middle.

(C) that voltage of 220,000, is maintained steady at the receiving end and of 245,000 volts at the generator end.

(D) that the voltage is maintained constant at both ends at 245,000 volts.

Fig. 1 also shows the power factor at both ends for each of the four assumptions and the voltage at the middle of the line for (A) and (C).

These four cases are chosen to illustrate the relative effect on efficiencies and power factors of these variations of voltage.

As a matter of interest the efficiency of one half the length of this line, giving a transmission of 250 miles is added in Fig. 1 with 220,000 volts maintained on both ends.

Method (*A*) shows the same voltage at both ends, viz. 220,000 with no limitations on the voltage at the middle of the line, which will rise above the ends on light loads. Method (*B*) the same voltage at both ends and in addition the voltage at the middle stabilized at the same value. This can be accomplished by placing a step-down station at the center of the line with synchronous machines of some sort provided with automatic means of fixing the voltage.

The effect of this middle station as far as voltage conditions go is to divide the line into two lines, each of half the total length. Since the voltage at the middle of the line is maintained constant either half of the line may be considered as a line independent of the other half, except that the energy delivered by the receiving end of the first line must equal the energy delivered to the second line (plus the energy loss in the synchronous

2. As a matter of information it may be noted that the "Equations" of this line are

$$V \sin \varphi = .532\, S \sin (\theta + 5° 4') + 606.5\, Q \operatorname{Sin} 84° 58'$$

$$I \operatorname{Sin} \psi = .532\, Q \operatorname{Sin} 5° 4' - 0.00119\, S \operatorname{Sin} (\theta - 88° 56')$$

Where
V = Generator voltage
S = Load voltage
I = Generator current
Q = Load current
θ = Angle of advance of S over Q
$\cos\theta$ = Power factor of load
φ = Phase of V
ψ = Phase of I
$\cos(\varphi - \psi)$ = Power factor of generator current

From these equations any desired set of terminal conditions may be calculated.

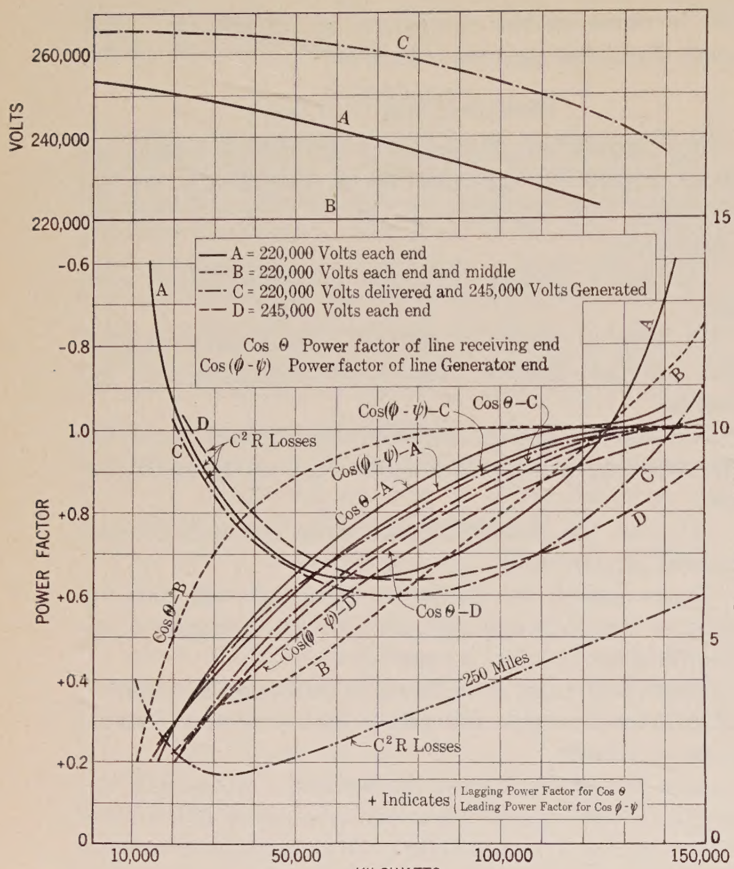


Fig. 1—Power Factor and Line Loss

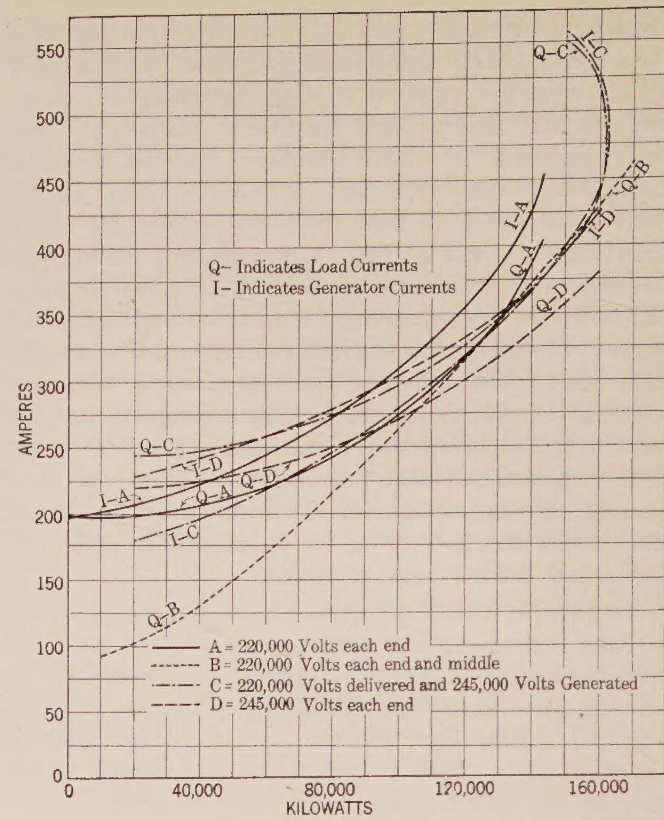


Fig. 2—Generator Currents

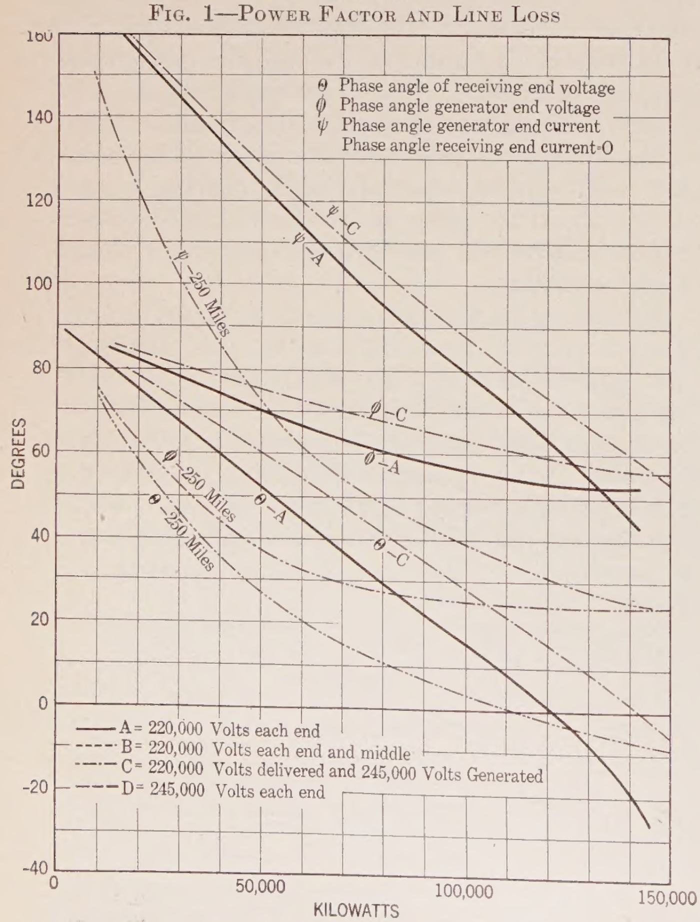


Fig. 3—Phase Position of Voltages and Currents Phase of Load Current Assumed as O

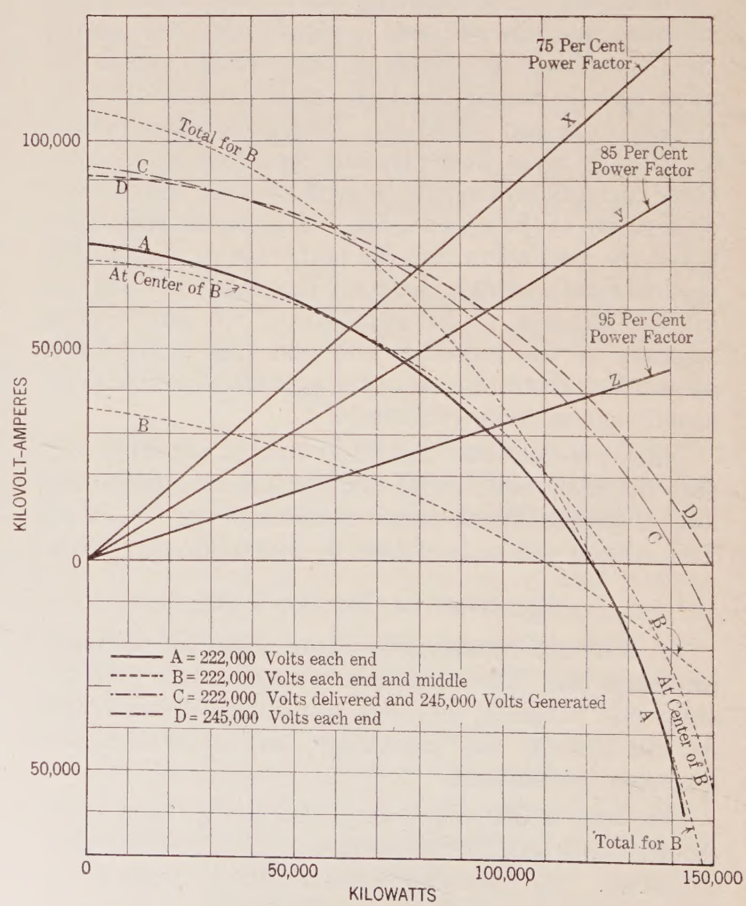


Fig. 4—Out-of-Phase Kilovolt-Amperes for Various Loads, Receiving End

machine) unless some load is taken off or some power supplied at the middle point. It is of course necessary that the synchronous machine at the center supply all the out-of-phase kilovolt-ampere required to maintain the receiving end of the first half at 220,000 volts and all that is required to maintain the sending end of the second half at 220,000. The kilovolts required for these two purposes may be of the same sign or opposite sign according to the load and the power factor and the resultant may be leading or lagging. This is the constant voltage transmission recently recommended by Baum.

Method (*C*) is to show the effect of a 10 per cent slope of potential in the direction of the load.

Method (*D*) is to show the effect of a 10 per cent increase in voltage over Method (*A*), the voltage being 245,000 volts at both ends.

With regard to the power factor curves of Fig. 1 it should be remembered that for any particular value of energy delivered the voltage assumed can be attained only with the load power factors shown.

To further illustrate the relations of these quantities Fig. 2 is added showing the currents at the two ends of the line with varying loads and Fig. 3 to show the relative phase positions of the voltages and currents at the ends of the line, the load current phase being taken as 0.

Since the delivery of any desired load at a definite voltage requires that the power must be delivered at a definite power factor, the synchronous condensers at the end of the line must be prepared automatically to deliver as much leading or lagging kilovolt-amperes as may be required and if they cannot supply this amount of energy the voltage will change appropriately.

As a practical matter of cost, the kilovolt-amperes required to maintain this prescribed power factor is a most important matter. These kilovolt-ampere quantities for controlling the line are shown in the set of curves in Fig. 4.

Three curves are added, marked *X*, *Y* and *Z*, showing the out-of-phase kilovolt-ampere component of the *load* the curve *X* being for a load power factor of 75 per cent, *Y* for 85 per cent and *Z* for 95 per cent. The condenser must supply both of these out of phase quantities.

Some comments may profitably be made on the curves of Figs. 1, 2 and 3. The efficiency curves no longer have the old familiar form. Good efficiencies are obtained only over a short range. The use of a middle point condenser station changes the form of the efficiency curve as seen in Fig. 1 in curve *B*. While the line losses are less with the middle point station at high and low loads, they are greater over the operating range and this without including transformer and condenser losses.

As would be supposed the maximum output occurs with power factors pretty near to unity.

The voltage at the middle of the line runs 15 per cent high at no-load with both ends at the same voltage, but only 10 per cent high when the sending voltage is 10 per cent higher than the receiving voltage.

The phases of the voltages and the corresponding phase positions of the machine armatures vary over an astonishing range, some 135 deg. for different conditions.

Special Conditions

The following special conditions on this line are of interest.

If the receiving end of this line be open-circuited and the generated voltage maintained at 220,000 volts, the open end will rise to 413,000 volts and the charging current will be 302 amperes, case 4, Table "A".

If the receiving end be short-circuited and 220,000 volts maintained at the generator, the generator current will be 223 amperes and the current at the receiving end will be 420 amperes. The power at the generator will be 7470 kw. at a power factor of 0.176 lag, case 8, Table "A".

Should the synchronous condenser pass out of step with the voltage at each end 220,000 volts, the maximum possible current that would be developed would be about 640 amperes approximately, the same on both ends. At the moment of maximum current the power factor would be 0.182 lag at the generator, giving a drag of 44,000 kw. with a negative load of 12,700 kw. at the receiving end with a power factor of 0.053 lead.

This condition is transitory but existing momentarily as the synchronous machines pass the condition of maximum current, case 7, Table "A".

The minimum line current with the voltage of 220,000 at both ends will be 196 amperes as shown in Fig. 2, with a load delivered of 10,000 kw.

The maximum power that can be delivered by the generator theoretically with its voltage kept at 220,000 as distinguished from the maximum current, is 166,000 kw. and will occur with the generator current about 441 amperes with a power factor of 0.986 lagging and the load delivered would be about 143,000 kw., the load current about 405 amperes at a power factor of 0.925 lead, if the load voltage is kept at 220,000 volts, case 3, Table A.

If in this last case the load voltage drops to 110,000 the maximum power that can be delivered by the generator will be about 94,000 kw. and will occur when the generator current is approximately 332 amperes and power factor 0.745 lagging and the energy at the load end will be about 75,000 kw. with current of 433 amperes and a power factor of 0.90 leading; case 6, Table A.

These conditions and several other special conditions are fully tabulated for convenience in Table "A".

Important as are the above features of the superline, the operating characteristics are more so and involve some most interesting discussions. Various aspects will be considered in turn.

TABLE A—500-MILE, 60-CYCLE TRANSMISSION

Case Number	Kw. on Generator High-Tension Side Transformers	Generator Power Factor "—" = leading	Generator Current, amperes I	Relative Phase Positions Load Current = 0: Generator Voltage φ	Generator Current ψ	Load Voltage θ	Voltage, kv. Generator End	Voltage, kv-Load End	Kw. in Load-High Tension side	Load Power Factor, taken in Line "—" = leading	Current of Load, amperes	Line Energy Loss, %.	
				500 Miles—Voltage Constant at Both Ends. 220,000 Volts									
1	108,400	−.922	308	56° 30′	79°	15° 30′	220	220	100,000	+.962	272.5	7.64%	Normal full load
2	132,200	−.984	354	53° 20′	63° 30′	0 50′	220	220	120,000	+.999	316	9.27%	Maximum load, to be taken as required in emergency
3	166,000	+.986	441	52° 30′	43°	22° 27′	220	220	143,000	−.925	405	..	Maximum possible deliverable power, approximate
4	8,060	−.070	302	5° 4′	91° 4′	0	220	413	0	..	0	..	Line open at load end
5	1,660	−.0233	195.3	90° 30′	179° 10′	90°	220	220	0	..	198	..	No load at receiving end
6	94,080	+.745	332	69° 45′	41° 51′	−25° 4′	220	110	75,000	−.903	433	..	Maximum power possible with half voltage load end, approximate
7	44,400	+.182	640	80° 50′	1° 0′	−93°	220	220	−12,700	−.053	640	..	Maximum possible current, approximate
8	7,470	+.176	223	84° 58′	5° 4′	..	220	0	..	..	420	..	Short circuit on receiving end
9	70,800	−.722	253.3	64° 30′	107° 30′	39°	220	220	66,667	+.784	225	6.4 %	Two thirds of normal full load
				500 Miles—Voltage Constant at Both Ends and at the Middle. 220,000 Volts									
10	300,000	+.82	960	..	..	..	220		220,000	..		27%	Maximum possible delivered power, voltage fixed at 220 kv. at middle of line
11	108,640	−.973	..	..	..	..	220	220	100,000	+.998	..	7.96%	Full load with voltage fixed at middle point by condensers at 220 kv.
12	63,400	−.878	..	..	..	..	220	220	60,000	+.931	..	4.83%	6/10 Full load with voltage fixed at middle point by condensers at 220 kv.
13	132,640	−.992	..	..	..	..	220	220	120,000	−.999	..	9.55%	Maximum load taken as required in emergency, witn voltage fixed at middle point by condensers at 220 kv.
				500 Miles—Voltage Constant at Both Ends. 245,000 Volts at Generator End, 220,000 Volts at Load End									
14	10,700	−.907	279	63° 0′	87° 0′	27° 40′	245	220	100,000	+.885	296	6.5 %	Normal full load
15	205,000	..	480	58°	37°	−22°	245	220	166,000	..	463	..	Maximum possible delivered power, approximate
16	104,000	+.812	302	70° 45′	35°	− 5° 4′	245	110	83,660	−.996	443	..	Maximum power possible with half voltage, load end, approximate
17	62,480	+.554	266	77° 24′	21°	− 5° 4′	245	55	43,400	−.996	458	..	Maximum power possible with quarter voltage, load end, approximate
18	48,800	−.625	184	102° 40′	231° 20′	120°	245	220	−52,000	+.50	274	6.16%	Example — half load delivered backward over line
				250 Miles—Voltage Maintained Constant at Both Ends. 220,000 Volts									
19	104,000	−.97	282	24° 45′	38° 50′	3°	220	220	100,000	+.998	262	4.0	Normal full load
20	126,000	−.99	336	23° 15′	31°	− 2° 40′	220	220	120,000	−.999	316	4.77	Maximum load taken as requred in emergency
21	130,800	+.688	523	..	..	..	210	110	111,760	1.0	588	..	Maximum possible power delivered—half voltage at load, approximate
22	70,000	+.352	681	..	..	..	210	55	62,060	−.866	755	..	Maximum possible power delivered—one quarter voltage at load, approximate

Starting

When one end of a super transmission line is open and the other end excited, the voltage at the open end rises very high; in our case to 413,000 volts from 220,000 volts. This is an impracticable operating condition and the open-circuiting of either end of the line cannot be permitted. Fortunately the maximum current that can be gotten steadily by any combination of conditions is not greatly in excess of full-load current at the receiving end so that for the duration of a starting period or an emergency, such as a short circuit or falling out of step, no damage would be done to apparatus permanently connected to the line, even if its capacity be considerably less than the full current of the line, while an excessive rise of potential would be prevented.

If it be then assumed that the synchronous apparatus at the receiving end of the line be permanently connected to the line the problem of starting may be cared for in several ways.

(a) The generator may be excited and started up from rest and the synchronous condenser will fall into step as the generator comes up to speed.

(b) The generator may be brought up to speed with

the field open and then the exciting of the field will start the synchronous motor, if properly designed, which will then pull quickly into step.

(c) If means for revolving the synchronous condenser be provided, both this machine and the generator while still connected may be brought up to speed and they lock into step when their speeds become equal.

It is not the purpose of this paper, however, to discuss the details of starting, but merely to point out how the starting may be practically accomplished.

Synchronizing

Synchronizing may be accomplished in the low tension at either end. As a matter of fact, as a first approximation this superline is in some ways the equivalent of a very high reactance connected between the synchronous machines at the two ends of the line, so great in value that to get full power over the line it is necessary for the two synchronous machines to swing out of step by a very wide angle, thus developing enough voltage to support full-load current.

Considering "*A*" in Fig. 3, the difference in phase of the voltage of the two synchronous machines at the two ends of the line changes from about 5 deg. at a load of 8500 kw. to about 70 deg. with a load of 140,000 kw. That is, if a line with synchronous condensers carrying no load is connected at one end to a similar line loaded, there will be a very wide phase difference between the voltages at the unconnected ends of two lines. When these are connected, however, their phases will come together and the load will divide between them. However, while under the assumed conditions the line conditions can adjust themselves without disturbance on synchronizing at the second point, the condenser must adjust its position more slowly and may cause some heavy current interchange with other condensers but it will very likely be possible to accomplish synchronizing in a manner to avoid such a violent change in the phase position of the condenser. This is a matter of interest rather than a serious difficulty of operation. However, syncroscopes used in the ordinary way would not indicate at all correctly, as to the proper moment for closing the synchronizing switches. Of course, if one end of the two lines is already connected, the other may be also connected without use of a synchroscope, provided it be proper to make this connection at all.

Synchronizing a lone line with an operating substation works differently. If the line be idling the phase of the voltage at the receiving end will be nearly in phase with that at the generator end, as there is little load passing over the line. If it then be synchronized with the load system already operating there will be no immediate change, for the phase of the generator must advance relatively by many degrees before it can take much load. This will occur in a few cycles if the governor of the generator prime mover be set to take such load. It must also drop behind many degrees to take power from the main system. This adjustment of position will occur very quickly in actual practise.

Presumably this connecting of an idle line to the substation is the proper condition for synchronizing. The governor of the generator prime mover can be set for higher speed to cause it to take load when the synchronizing has been accomplished. If one line thus synchronized to a substation is then to be paralleled on the generator end with other already synchronized lines, it should be so loaded (the voltage being maintained constant automatically) that the generators are all in phase before closing the synchronizing switch at the generator end.

While synchronizing is not likely to cause much difficulty, the matter of pull-out torque and holding in synchronism through electrical trouble is much more difficult. If a generator feeds a superpower line synchronized at the receiving end with a load system and a sudden increase of load comes the load system will tend to slow down momentarily. To escape losing synchronism the generator must slow down also, but to accomplish this slowing down, more load must be passed over the transmission line. If now the generator be already loaded as far as the line will permit *by efficiency and voltage* considerations, as for example to 140,000 kw. it will be found by examining the curves of Figs. 1 and 2 and case 3 Table "A" that very little more load can be got over the line. If, however, a certain margin exists so that the normal full load over the line may be increased by perhaps 50 per cent when called upon by a load increase, then a sudden increase of load and slowing down of the load system will cause an increase of power delivered over the line and the generator will slow down, if properly designed, especially if it be a waterwheel with the usual small overload capacity and if its governor have a wide range of speed variation with load.

Again, if a local short circuit occur in the load system near the receiving end of the line, the local voltage will drop, which greatly limits the power that can pass over the line as shown in cases 6, 15 and 16, Table "A" and the generator will immediately tend to pull out of step if the rest of the system *tends to slow down.* Obviously this is a more serious matter and at first sight a most difficult one to handle.

Cases 21 and 22 of Table "A" show that a line of half the length is considerably better and that the maximum power that can theoretically be delivered is greater than for the full length of line with the same terminal voltages. A further treatment of this subject will be found below:

Typical System Diagram

The determination of the best arrangement for the use of breakers on the superpower line and its connected load network, when taken in connection with automatic relay protection for short circuits, will be found to be a very complex matter. The purposes of this paper,

which is largely illustrative, will be best served by assuming a layout which is well suited to the usual conditions and discussing its action under various normal and abnormal conditions. Such an arrangement is shown in the one line diagram in Fig. 5.

It will be assumed that the line voltage is normally maintained automatically at 220,000 volts 60 cycles, at each end by regulators working on the fields of the generators and condensers. The amount of synchronous capacity required for various cases is shown in Fig. 4.

The four circuits, which may well be carried by two two-circuit tower lines, make a well rounded super transmission installation. One circuit may be taken out for repairs and the other three lines be made to carry the total or nearly the whole power.

This overloading of the three remaining lines calls for a very large capacity of synchronous condensers. By reference to Figs. 1, 2 and 4, it will be seen that the demands on the synchronous condensers will be less excessive if at the same time the voltage at the generating end be raised even by such a small amount as 5 per cent and this should be permissible for temporary operation. In this case account is being taken of the requirements of the load as well as the line. This resultant will be the difference between the *X*, *Y* and *Z*, and the *A*, *B*, *C* and *D*, curves.

Synchronous Condensers

We may take as an illustration 400,000 kw. as the total normal load on the transmission with 220,000 volts at each end. This means 100,000 kw. delivered per circuit. From the curves, case 1, Table "A" it will be seen the normal generator power factor is 0.92 leading. An approximate capacity of 115,000 kv-a. is required, but to cover somewhat less favorable contingencies and some overload, 130,000 kv-a. may be taken at a power factor of 90 per cent. If the prime movers are waterwheels they will presumably be given a *maximum* continuous rating corresponding to about 140,000 kw. per circuit.

As to the condensers, we must always satisfy the condition when the line is disconnected from the load circuit, which calls for out-of-phase kilovolt-amperes of about 75,000 kv-a. lag (see Fig. 4) on the line. This means 78,000 kv-a. lag on the condenser terminals. Condenser capacity to meet this no-load condition must be furnished, whatever loading may be assumed for full load. The effect of raising the voltage of the sending end of the line is seen from case *C*, Fig. 4, viz., to increase the no-load kilovolt-amperes required. The *full load* kilovolt-ampere requirements, however, will be less with the higher generator voltage.

Strangely the major part of the charging current is fed from the lower voltage end. This is because the voltage naturally rises along an unloaded line away from the generator. By referring to case 4, Table "A", it is seen that if the receiving voltage were raised to 413,000 volts, this end would supply no charging current at all.

In order, however, to take account of the effect of transformers and condensers we may assume that if the load at the receiving low-tension bus bars is 100,000 kw. at 85 per cent power factor the load will be 105,000 kw. in the high tension, allowing for transformer and condenser losses. The high-tension out-of-phase component of the *load* will be 71,500 kv-a. lagging, assuming the transformer has 8 per cent reactance e. m. f. The line delivering 105,000 kv-a. requires 22,500 of lagging kv-a., giving 49,000 kv-a. lead to be supplied by the condenser in the high tension. Therefore, the kv-a. required from the condenser in its low-tension circuit is 51,500 kv-a. lead, assuming a 5 per cent reactance in the transformer tertiary winding. This is well within the capacity required for the light line running, *viz.*, 75,000 kv-a., the difference being available as overload capacity.

If one line be down and each of the remaining lines deliver 133,000 kw. low tension, the high-tension, out-of-phase kv-a. of the *load* (85 per cent power factor) on the 220,000-volt busbars is 94,000 lag. The out-of-phase high tension required by the line is 47,000 leading, giving a total condenser requirement of 141,000 kv-a. lead on the high-tension side and 5 per cent in excess on the low-tension side or 148,000 kv-a. lead. The amount is far in excess of that required for light line and this is not a desirable operating condition.

Various expedients may be used to reduce this requirement of 148,000 kv-a. For example:

(1) If one line is taken out, the total load required of the system may usually be somewhat reduced, say to 120,000 kw. per circuit, which will naturally reduce the requirements from the condensers.

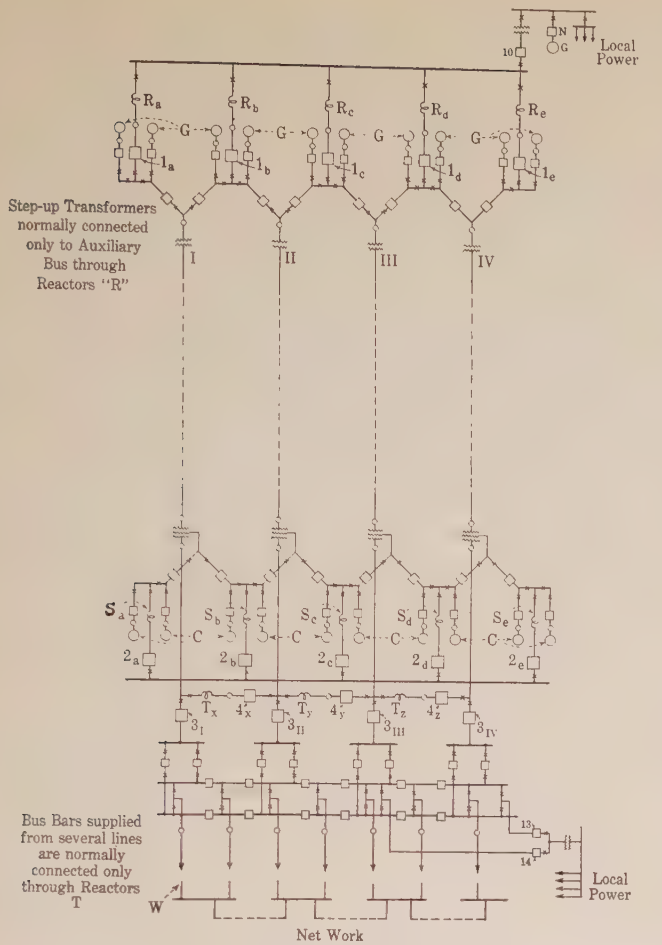
(2) If the generator voltage be raised 10 per cent to 245,000 volts, the requirements of the condensers will be reduced to 95,000 kv-a. lead which is somewhat more than the no-load requirement.

(3) If the power factor of the load at the step-down bus bars be raised to 95 per cent, the kv-a. out of phase of the load is 55,000 high tension, giving with the 47,000 required by the line, $102{,}000 \times 105 = 107{,}200$ lead.

(4) Since when one line is down its condensers are not in use, these may be added to give additional capacity to the three good lines. This will bring the available condenser capacity for each of the three operating lines to 133 per cent of normal, or 100,000 kv-a. if normal be taken as 75,000 kv-a.

(5) Normally spare capacity will be provided for condensers, and if it be assumed that this may be used when one line is out and the spare be 20 per cent of the total as in the system of Fig. 5, there will be capacity of two extra condensers for the three circuits which will provide the requisite capacity for 133,000 kw. delivered, counting somewhat on overloading.

However, it would no doubt be more practicable



Ⓖ —Main generator and prime mover, 65,000 kw-95 % P. F. units.

Ⓒ —Synchronous condensers, 75,000 kv-a.

[1] —Automatic oil circuit breaker.

□ —Oil switch, non automatic.

× —Disconnect switches, air break.

—Relays for breakers—actions as described below.

—Reactors—at generator station—to pass 400,000 kv-a. on full voltage at condenser end—to pass 300,000 kv-a.

—Step up transformers—130,000 kv-a. Internal reactance as low as practicable, say 8 per cent.

—Step down transformers, 110,000 kv-a. on secondary, and 75,000 kv-a. on tertiary, reactance between primary and secondary say 8 per cent. Between primary a nd tertiary—very low—say 5 per cent and between tertiary and secondary very high say 12 to 15 per cent.

—Feeders to network.

FIG. 5—ONE LINE DIAGRAM OF TYPICAL SYSTEM SUPERPOWER TRANSMISSION

In generator leads, relay kills the field of its own generator but only while short lasts; inverse time limit 0.2 seconds on 750,000 kv-a.,—0.5 seconds on 400,000 kv-a.

In lead to breaker [1], relay overload instantaneous, minimum setting 160,000 kv-a.

In high-tension of step up transformers, relay instantaneous to ring a bell as long as power factor is below 50 per cent, lagging.

In primary of step down transformer, (or a combination of currents representing tertiary and secondary windings to give the same result) relay to open breakers [2], [3] and [4], instantaneous, minimum setting 175,000 kv-a. Also opening [2], [3] and [4] when power factor drops below 50 per cent leading (as motor), in 3 seconds.

In leads to step-down transformer secondary, relay opening [3] in 0.4 seconds.

In leads to synchronous condensers or to transformer, relay opening [2] inverse time limit 0.2 seconds on 400,000 kv-a., and minimum operating value 100,000 kv-a.

In leads to switch [4]—relay definite time limit 0.75 seconds—minimum operating kv-a., 125,000.

In feeders, relay inverse time limit but clearing any short as high as 100,000 kw. in less than 0.25 seconds.

Standard protection for short circuits for generators and local station power.

to count on operating only 120,000 kw. on each of the three remaining circuits when one goes out, thus requiring 95,000 kv-a. lead from each synchronous condenser, this being based on a network load power factor of 85 per cent. Even with this arrangement some of the idle condenser capacity should be used for continuous running at 120,000 kw. generator.

Apparently a very effective arrangement could be secured by providing to have the generator voltage automatically run lower on light load and higher on heavy load. A change of 5 per cent would be an important help and one of 10 per cent would greatly reduce the required condenser capacity.

Thus it is seen that for economic conditions involving the transmission of very heavy loads, capacity in synchronous apparatus may be required numerically in the neighborhood of the amount of the load transmitted. On the other hand a number of simple expedients may be used to materially curtail these requirements. It should be clearly understood that the values so far given are not intended to indicate that these are practicable for an actual installation. They are offered as a basis for discussion. No doubt more consideration will be given to these subjects before such an installation will be made.

It should be noted that to maintain constant voltage on the high tension at full load or with the overload condition, that voltages on the condenser circuits must be regulated to be a little above or a little below the line voltage according to whether the passing of power causes a rise or a fall of voltage in the transformers. For this line and normal full load there will be a drop through the step down transformer and the condenser voltage should be at a lower value than the ratio of turns of the transformer and the line voltage would indicate. This refers to the ratio of turns of primary and tertiary windings. If the load be increased for example, to the point where three lines will carry the load of four or under the conditions when a sudden disturbance calls for a still larger flow of current the condenser will be forced to supply a leading current and the drop in the step-down transformers will become a rise, so that the condenser terminal voltage must be higher than the ratio of turns would call for. The synchronous condenser must be adapted to sustain this condition. Since the primary and tertiary windings are closely related magnetically, these voltage variations will be small.

Similarly at the generating end the voltage regulator must be laid out to correct for the voltage drop or rise of the step-up transformer. Space will not permit a fuller discussion of this point at this time.

As a matter of good design, it is likely that it will be more favorable to provide most of the power factor correction as far as it is required to raise the power factor of the load by synchronous apparatus in the neighborhood of the load itself as this will improve the regulation and efficiency performance of the network as well as adapting the load to the requirements

of the line. It will also reduce the kv-a. load on the step down transformers. For this purpose any available existing synchronous apparatus would serve. The part of the corrective kv-a. that must be varied during changes in operation should be under immediate control and should be supplied by condensers at the step-down station.

For spares add a fifth unit to generators and condensers.

The original assumption of the loading of the line may now be modified to give a favorable layout as follows:

Normal full-load 400,000 kw., 100,000 per circuit on the distribution bus bars (requiring 420,000 kw., 105,000 per circuit on the high-tension side at power factor of 98 per cent lagging). Condenser kv-a. required per circuit 24,000 kv-a. lagging including requirement of step-down transformer, assuming *load* corrected in the network to *unity power factor* at the high-tension side.

Kilovolt-ampere required for no-load condition 79,000 lag per circuit on condenser terminals (only occasionally and for brief periods).

Maximum steady load provided for on three lines 360,000 total, 120,000 per circuit on distribution bus bar (380,000 kw., 127,000 per circuit on high-tension side at power factor 0.995 per cent leading) calling for 11,400 kv-a. per circuit leading on condenser terminals assuming the load corrected in the network to unity power factor at the high-tension side.

Capacity of condensers provided 75,000 kv-a. per circuit. Note that when the 79,000 kv-a. above is required on no-load that the spare condenser can be called upon should this condition continue indefinitely. The extra condenser capacity on the over load condition is highly desirable as a margin for operating reasons. Sufficient corrective capacity must be provided in the network (or at the condensers) to bring the load power factor to unity. The amount of this is shown for various power load factors in Fig. 4.

Efficiency of line, normal 92 per cent, loss 8 per cent; add transformer loss 2×1.5 per cent and condenser losses 4 per cent of 75,000 kw. total 14 per cent loss.

Step-up transformer capacity 130,000 kv-a. per circuit, step-down transformers capacity for load winding 110,000 kv-a., for tertiary winding 75,000 kv-a. This apparatus will carry the overload corresponding to one line out as above, until additional capacity can be added, but will be sensitive to voltage drop.

Generator capacity 130,000 kw. per circuit at 95 per cent power factor.

It should again be noted that this layout is proposed for discussion as a maximum and optimum system and no doubt a more conservative design would be adopted in any particular installation.

Switching

Considering the layout of Fig. 5 more particularly from the point of switching, the most conspicuous characteristic is the omission of all breakers or automatic oil switches in the high-tension circuits. This will be seen to have several important advantages and few disadvantages.

(a) It protects the line from accidental open-circuiting at either end and the very high voltage resulting at the open point.

(b) It eliminates a number of high-tension insulation points and greatly simplifies the high-tension layout.

(c) It eliminates a large item of cost and maintenance. Such a system as in Fig. 5 laid out in accordance with the usual practise would call for from 25 to 30 high-tension breakers at a cost of perhaps over a half a million dollars.

(d) The principle disadvantage of the omission of high-tension switches is the limitation of flexibility; for example, if a line is down in the layout of Fig. 5, its transformers are also down and similarly with the line if its transformer is down. If high-tension disconnect switches are installed any desired reconnection of lines and transformers may readily be obtained, but only at the expense of shutting down another line to make the change in the case of some operations. This use of disconnects in this particular situation offers several very interesting possibilities which space will not permit discussing here.

It may well be argued that for such a system as Fig. 5, feeding into a large network with other generating stations of large aggregate capacity, the simplicity of this layout is of great advantage. Here there is the one function of carrying a large block of power, 24 hours a day with no occasion for changing of connections except in case of some accident and for the regular inspection of generators and condensers. This inspection is provided for by the spare units shown which can be switched in and out one at a time without disturbing load. In case of emergency or to make the infrequent inspections of transformers and lines (that is—such line inspection and testing as cannot be done alive), three lines can be made to carry nearly the load of four. Ordinarily, however, when one line is to be shut down it will be feasible to arrange for a reduction of the load by 10 or 15 per cent on the transmission system. With careful line inspection and maintenance it may be confidently expected that trouble in the major elements of the system will be very rare. This favorable result assumes a very careful design, with the most painstaking scrutiny of details, but not an elaborate or excessively conservative design. The important thing is not to have an extreme factor of safety, but to insure an adequate factor of safety at *all* points. In making this statement as to the rarity of major trouble, reservation must be made to cover the possibility of some unusual and unexpected local disturbance. Such a condition might be malicious interference or one of the rare locally occurring fog belts which coat insulators or (possibly but very improbably) extreme lightning severity, etc.

At this point I would like to state that the practise of working on live lines at 100,000 volts and higher is worthy of most serious consideration on these super lines. While at first thought this practise seems dangerous, a more careful analysis does not bear out this appearance; neither does the experience with such work. I think there is little question that live line testing of high-tension insulators is feasible and reasonably safe. It has already been carried out very extensively. The question then arises whether very simple line operations are not also feasible. The best example of such a simple operation is the changing of an insulator string and this is the most useful operation in practise. A little consideration will show what a wonderful advantage the possibility of changing defective insulators without taking load off the line would be, especially in a line of the length of the one under discussion. In my judgment this advantage is so great as to warrant very considerable exertions. Some superintendents who do not care to do this work with their own crews may obtain more or less the same result by contracting to have their defective insulators changed periodically by outside expert crews as has already been done in many cases. While there will naturally be a great inertia of conservatism holding back the adoption of live line work, such as insulator changing, it is difficult to see how it can be logically ruled out in the end, when the live line testing is already pretty well accepted.

Automatic Relay Protection

Most of the features of the relay protection of Fig. 5 involve the standard use of standard apparatus but there are a number of novel features. The most satisfactory way of bringing out the intended operation will be the analyzing of the effect of various possible accidents. Single-phase grounds and short circuits will have the same effect on these lines since the high-tension neutral is assumed substantially dead grounded at a sufficient number of points. Assume all the generators except the right hand pair are operating, each pair on its own line and all breakers [1] closed, also all condensers except the left hand pair operating, each pair connected to its own transformer and all switches [2] closed; also all breakers [4] closed but distribution bus bars all operated in four groups.

A—Short Circuit on Generator End of Line I

The relays in the leads of the generators feeding the short circuit kill the generator fields, operating in 0.6 seconds. The breaker [1-*a*] will open instantaneously opening about 300,000 arc kv-a.; the other breakers [1] do not open as the current will be too small. The short circuit is then killed as far as the generating end is concerned. Meanwhile the only effect at the receiving end is to develop a current of 223 amperes and to change the power factor of the line to say 18 per cent leading (Table A, Case 8) (current would be lagging if condenser is considered a generator) and to drop the delivery of power that had been passing over this line. Through the action of a relay designed for this purpose, this low leading power factor in the step down transformer primary will open the breaker [3-I] in 3 seconds and at the same time [2 *b*] and [4 *x*]. This disconnects the line entirely from the system but leaves both generator and condensers connected and running. If this renews the short circuit the generator fields will be restored and the condensers fall into step again or, if so designed, once opened, the generator field circuit may remain open in which case the condenser will come to rest and restarting will be necessary. The delay of three seconds is to give the short circuit a chance to clear. No harm is done, since the short circuit will not pull more than about 7500 kw. to 15,000 kw., (Table "A", case 8) and less than full-load current. When the operators see that one line is out they should immediately connect in the spare generators and condensers. If the bad line can then be put in again this may be done at once, but otherwise the full load or a suitable portion can be taken over the three good lines. In case of the dropping out of line *I*, the three water-wheels still on the line will open up their governors and may take load up to the extent of their capacity—say 20 per cent excess making, 60 per cent excess in all of the loss from the bad line and the rest of the load will be taken by the generators in the network. If the latter have more sensitive governors they may take still more of the load. The steady distribution of the load between line circuits can be controlled at will by hand adjustment of the speed of the generator governors.

When the opening of [3-I] cuts off certain feeders to the network, the corresponding load will presumably be supplied around through the network by other routes over the good circuits.

B—Short on primary leads of step up transformers

Substantially the same actions as in Case "*A*", but currents will be 50 per cent heavier.

C—Short circuit on auxiliary bus, generator station

All breakers [1] go out instantaneously and before the relay in the generator leads can open the fields, since these are inverse time limit and the short circuit is limited by the reactances. No other effect will be produced as the line units can all run perfectly well without the auxiliary connection. A short circuit on the auxiliary bus should be very rare.

D—Short circuit at condenser end of line I

Breaker [3-I] opens instantaneously from relay on primary of step-down transformer and [2 *b*] and [4 *x*] are open by the same relay. Nothing happens at the generator end until the attendant cuts off this line at his leisure. The generator end current will be only 223 amperes (Table "A", case 8) and the current at the load end only 420 amperes. It might be well to have the low generator power factor 0.176 lag, ring a bell to call attention to the condition.

E—Short at the middle of the line 1

This will pull 640 amperes at the generator end and cut off the generator fields, which will open [1-*a*] in 0.5 seconds clearing this end. It will act the same as *A* at the receiving end, [3-1], [2-*b*] and [4-*x*] going out by the same relay.

F—Short on left hand operating condenser leads

Corresponding breaker [2] opens in 0.2 seconds leaving line to go down as in *A*—[3-*I*] opens in 0.4 seconds and [4-*x*] in 0.75 seconds.

G—Short on condenser auxiliary bus

Breakers [2] go out in 0.2 seconds clearing the trouble without disturbing the operation, provided synchronism can be held. If reactances are used with switches [2], conditions will be much easier.

H—Short on distribution feeders

[3 *x*] opens in 0.4 seconds on overload leaving the power from line 1 to pass through [4 *x*] to the other feeders and into the network where it would find its way to the original destination. The time limit of 0.4 seconds is to permit a feeder breaker to clear the individual feeder before [3 *x*] opens. If [3-I] fails to clear the circuit [4-*x*] opens in 0.75 seconds and line I will be disconnected.

The protection of the local station power circuits involves no particularly difficult problems and need not be discussed here.

Synchronizing Power in Typical System

As already pointed out, the characteristics of the superline for efficient full-load transmission of power are so extremely favorable on account of the neutralizing of the reactance effect by the capacity effect, that for other conditions when this neutralization does not occur to the same favorable extent, as for example with overloads, very light load or low voltage, transmission becomes very unfavorable. The very light load condition has been considered above. The overload condition, as an overload problem, is the least serious and easiest to meet, but the low voltage or short-circuit condition is serious and difficult from the point of view of holding synchronism.

Before discussing this matter with regard to the system of Fig. 5, I will consider a single superline circuit such as one of the four here shown. It will transmit considerably more power than full-load power if the voltage at both ends be kept at normal even as high as 145,000 kw. (See Table "A", case 3). If, however, this voltage drop below normal, even if at the receiving end only, the amount of power that can be delivered is greatly reduced as seen in Table "A", case 6. For example, in this case the actual power delivered with half voltage at the receiving end is less than the full load, viz., only 75,000 and this condition gives nearly the maximum deliverable power for this voltage. Since, however, there is little likelihood that the failure to deliver *power* under conditions of abnormal voltages (due presumably to short circuits) will be *per se* of importance, since such conditions can exist for a period of perhaps only one or two seconds, we have only to consider the danger of loss of synchronism or the opening of breakers.

Several cases occur which have to be considered independently.

First, when a short circuit occurs at the receiving end of the system on the step-down side. In this case there is a tendency for the receiving end voltage to drop, which will tend to limit the amount of power delivered by a line. But the full input to the generator continues to be delivered by the prime mover, and the only thing that prevents its speeding up to the light load speed of the governor (considering now one circuit by itself) is such power as may be taken by the line. This is the most serious condition to be met in maintaining synchronism and will be critical when the short circuit is such as to tend to cause the network machines to *slow down;* for example, when the short circuit is through a feeder line with very little armature reaction drop in the generator voltage. Of course, the overspeed governor on the generator prime mover will prevent any dangerous increase of speed, but it will be useless for preserving synchronism.

It follows from the above that for this case the critical factor will be the load developed by the generator, not the load delivered by the line and this generated power may be considerably greater than the delivered power. For example, the drag on the generator in Table "A", case 6, is 94,000 kw. compared with 75,000 kw.

But short circuits are of many varieties. If of such a sort that the actual kw. developed in the short is less than at full load, on account of low power factor in the short circuit, the generators in the network and the main generators, at opposite ends of the line will tend to *speed up* and the load that can be delivered over the line in one direction or the other may be sufficient to hold them in step, even if less in amount than full load power. In this case the governors of the prime movers will have to ultimately control the speeds and the more nearly their speed curves are alike the better the chance of staying in step. The range through which synchronism would be retained would be, on the one hand that condition in which the receiving end prime movers speed up more rapidly than the main generators and are only restrained from exceeding the speed of the latter by the load sent backward over the line helping the prime mover to speed up the main generators and on the other hand the condition in which the main prime movers are just able to pull up the speed of the receiving end machines until equilibrium is reached. This is presumably a very wide range and successful operation through this range is not limited to line voltage conditions in which full load may be passed over the line.

In the case of a single line and a condition such that the prime movers in the net work at the receiving end tend to slow down, synchronism cannot be maintained if the receiving voltage on the line drops to the point

where full load cannot be delivered over the line. In this case it must be noted, however, that the critical voltage is the high-tension line voltage and not the step-down voltage. This is a very important distinction for the drop in the step-down transformer will be considerable on a short circuit especially if the design of the step-down transformer is such that the magnetic inter-linking of the tertiary with the primary is much closer than that of the tertiary with the secondary, for the short-circuit kv-a. supplied by the condensers must go through this step-down transformer before reaching the short circuit and this tends to sustain the line voltage. As a matter of fact, if the condensers were connected to taps in the grounded end of the primary windings some gain would result in close interlinkage. A heavy fly-wheel capacity in the condensers is presumably very helpful in maintaining stable conditions.

is, the restoring torque will develop at least *partially* with the *progressive* separation of the phase positions of the several prime movers generators. The form of curve connecting power transmitted with phase displacement (Fig. 6) shows a condition very favorable for suppressing the pendulum action without the machine getting out of step. Of course, proper *damping* devices will also be of *great* assistance.

Enough has been said to make it clear that for any given case the resultant action is very complex, involving the relative flywheel effects of the different units, their different short-circuit characteristics, their governor speed curves and the damping factor. It may very likely be that in an actual installation the most favorable adjustment of conditions may be secured by providing adjustment in such factors as flywheel effect, short circuit kv-a., etc., and making a

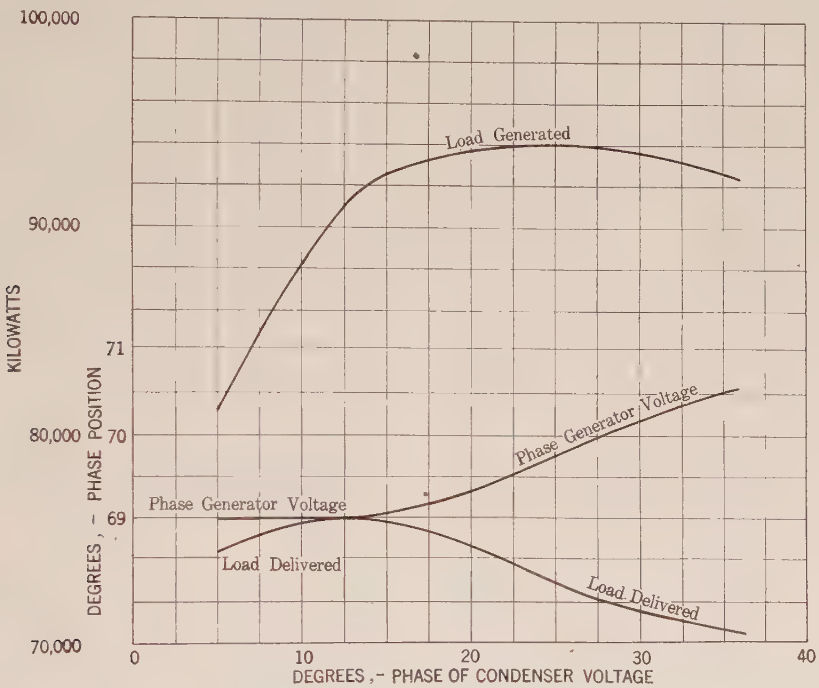


Fig. 6—Maximum Power Transmission

As has been pointed out by others, the tendency for the various parts of the system to fall apart is theoretically markedly increased by the pendulum effect between two machines starting in equilibrium under normal conditions and subject to a sudden changing in conditions due to a short or even load change due to switching. A new equilibrium position must be assumed and in swinging to this new position there will be a tendency to over run the position of equilibrium and if this position of equilibrium be the maximum torque position also, the temporary over run may cause a falling out of synchronism. The seriousness of this can be determined only after further data are available, for the percentage increase of torque required for maintaining synchronism may not be great and the changes will probably not be very sudden, that

final determination in the field. These are matters for the study of specialists and cannot be profitably carried further at this point.

This discussion so far applies to a single circuit or a group of circuits connected directly in parallel. The action of the system of Fig. 5, however, is in effect quite otherwise. There are several critical points of difference.

First: The four lines while dividing the load freely between one another, are yet sufficiently separate electrically so that a short circuit on one or on the step-down end of one will not greatly disturb the voltage on the others. The high-tension circuits are not directly connected, but the step-down transformers secondaries are connected together through choke coils having a suitable reactance to permit equalization of the loads.

A similar interconnection exists at the generator end.

Second: The synchronous condensers are in parallel and are thus able to hold strongly together at times of disturbance in the network. This serves to hold all four high-tension circuits together. If found desirable to prevent too much disturbance of a condenser by trouble on another line, reactances can be connected between each condenser and the auxiliary bus.

Third: The main generators are connected in parallel through reactances. This serves to tie these generators all in parallel so that no one generator is likely to drop out of synchronism.

Fourth: The feeders on the step down side of the four transmission circuits are so connected through the reactances that a dead short circuit on one will not greatly disturb the voltage of the others, which will, therefore, continue firmly in synchronism through any kind of disturbance, however severe.

Thus this combination of circuits, in addition to providing a simple and practical layout for segregating and disconnecting any circuit suffering a short circuit, will hold itself firmly in synchronism and in synchronism with the network in spite of any breakdown that may occur.

For example should a dead short circuit occur three miles out on the left hand local feeder, *viz.*, at *W*, Fig. 5, current would be discharged into it through the feeder from line *I*, from the condenser bus through the tertiary winding of the transformer and through breaker [4 *x*]. While the voltage would be dropped materially on the local bus fed by line *I*, depending on the reactance of the bad feeder, the high-tension voltage on the line *I* would be dropped to a much less extent and the voltage on the condenser bus very little. The current passed through switch 4 would probably not exceed 200,000 kv-a. which would be supplied partly from the network and partly from the three other lines and would leave the voltage on the three good lines practically undisturbed. Meanwhile the relays would cut off the fault.

This system, to use an analogy, compared to the usual system, is like a locomotive which has an equalized, spring supported frame, compared to the farmer's hay wagon without springs. Every stone in the road causes a shock to the whole wagon while it would be passed over by the locomotive almost unnoticed.

Summary

To give a more concrete idea, numerically, of the effect of abnormal conditions in producing heavy short circuits and to indicate the duty of the oil breakers, the following approximate values are given, assuming a load of 90 per cent power factor at low-tension busses.

	Kw.	Kv-a.
Normal full load per circuit, low-tension bus	100,000	111,000
Maximum synchronous converter load per circuit	3,000	75,000
Normal current in reactors (4) representing interchange of load, estimated	10,000	12,000
Short circuit in high tension at receiving end of high-tension circuit, arc kv-a. from generator, at point of short circuit, 420 amperes		160,000
Kv-a. corresponding at generator, 223 amperes		85,000
Kv-a. through receiving transformer from condensers and network about		1,250,000
of this say 200,000 comes through reactors (*T*) and 350,000 from network. Of the 200,000, part comes from network and part from three good lines, the balance of 750,000 from the condensers and tertiary windings		
Short circuit in high tension at sending end of the line—		
From the generators arc kv-a.		600,000
From the line, amperes 420		160,000
From the network and condensers at receiving end corresponding to 223 amperes high tension		85,000
Short circuit at center of line, from each end 735 amperes		280,000
From generators and also from network corresponding, 642 amperes each		244,000
Short circuit on generator auxiliary bus, each generator 350,000 all		1,400,000
Short circuit on condenser auxiliary bus, each condenser 350,000		
Each tertiary winding 350,000 part from line and part from network—total		2,800,000

Note: If reactances be installed in series with the breakers (2), this value can easily cut in half or less, but little would be gained as no one breaker has to handle more than 700,000 arc kv-a.

The essential features of the system of Fig. 5 have now all been touched upon and the performance of the whole system seems to be very favorable. Of course, many variations can be made and changes introduced to meet special cases, but as long as the essential characteristics are maintained, the good performance should still be retained. The more fundamental features are the maintaining substantially separate of the main units as far as short circuits are concerned, the interconnection for purposes of load equalization, the means of maintaining a high voltage at both ends of the line on the high-tension side even when short-circuits occur, the automatic control of voltage and power factor for purposes of regulation and the proper choice of governor characteristics and flywheel effects for the various units.

Intermediate Condenser Station

An intermediate station at the middle of the line with synchronous condensers materially improves certain features of the line performance as for example, synchronizing power at time of disturbance and variation of voltage along the line. Furthermore, a much smaller synchronous condenser capacity is required at the receiving end. This advantage is more than balanced, however, by the large condenser capacity required at the center of the line.

Considering the layout of Fig. 5 as distinguished from a single transmission circuit, apparently, on the whole, little or nothing would be gained in efficiency or operating performance by the intermediate condenser station. The no-load voltage at the center would be reduced 15 per cent which is a material point, the line efficiency over the working range would be no better and at least 30,000 kv-a. of condensers additional total would be required, representing a loss and expense. The synchronizing power would be materially greater, perhaps 50 per cent greater. On the other hand the extra cost, especially when spare apparatus and interconnections are considered, and the very serious operating handicap of a third station with a third set of operators to be coordinated and the problem of relay protection, make it clear that very considerable sacrifices would be justified in avoiding the intermediate station and retain the simpler layout of Fig. 5.

It is interesting to note from case 18, Table "A", that power can be transmitted backward over the line with 220,000 volts at the condenser end and 245,000 volts at the generator end and at a better efficiency than in the normal direction.

Conclusion

The net upshot of this layout of Fig. 5 is a system delivering regularly 400,000 kw. (perhaps reduced to 360,000 for brief intervals, for work on a transmission circuit) over a distance of 500 miles, with losses including line, transformers and condensers of about 15 per cent, with flexibility such that any unit may be shut down at will without disturbing operation. This is a system in which disturbance caused by short circuits will apparently be less than with the usual transmission system and a system well adapted for automatic relay protection.

On the basis of power generated at $20.00 per kw. year on the switchboard and saleable at the receiving step-down bus bars in quantity at $50.00 per kw. year, an expenditure of something between $75,000,000 and $90,000,000 would seem to be justified, assuming 12 per cent to be sufficient to cover all fixed charges, or $75,000 to $90,000 a mile for a double circuit tower line including cost of condensers and auxiliaries.

It appears from the above discussion that the superline, while it has great possibilities of astonishing efficiency and an extraordinary range of transmission, has also some very distinct limitations and some real problems of its own that will warrant much study and discussion.

High-Voltage Circuit Breakers

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Review of the Subject.—*The 150-kv. system operated for some years by the Southern California Edison Company has not made use of automatic operation of circuit breakers. The multiplication of generating stations and connections which accompanied the change to 220-kv. makes desirable the automatic sectionalizing of the line in cases of trouble and, therefore, requires circuit breakers for automatic operation similar to that obtained on more moderate voltage systems. Circuit breakers have been manufactured for this service with high rupturing capacity and the designs have followed closely the standard designs for more moderate voltages.*

It has been standard practise for some time to take care of fault conditions on moderately high-voltage lines of about 110,000 volts by the automatic operation of the high-voltage circuit breakers.

On the 150,000-volt circuits which have been operated for several years by the Southern California Edison Company high-voltage circuit breakers have been in service but have not been tripped automatically on the occurrence of trouble but, instead, there has been utilized a scheme of clearing high-voltage trouble by means of lowering the line potential.

In the case of flashovers this scheme has been efficacious. The operation has been entirely manual, the power house operator cutting in field rheostat by hand upon obtaining indication of ground current as shown by an ammeter connected in the neutral of the step-up transformers at the power house. With two power houses in service it has been necessary for the operators at the two plants to cut in field rheostat at the same time and approximately at the same rate. This has been found to be quite feasible.

With the growth of the system, involving increases in the number of power plants and generating units, and with the growing importance of absolute con-

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tinuity of service, it has been considered desirable to carry out a scheme of breaker operation similar to that used on the moderate voltage systems.

The 220,000-volt double-circuit line, which has this year been put in service by the Southern California Edison Company, has, therefore, been provided with automatic high-voltage circuit breakers and a relay system to give proper sequence of breaker operation on the occurrence of trouble. The lines from the Big Creek Power Houses to Los Angeles are sectionalized at two intermediate points by means of 220,000-volt circuit breakers and upon the occurrence of a flashover or other trouble on any section the particular section in trouble is separated from the rest of the system by the operation of the sectionalizing circuit breakers.

The Pacific Gas & Electric Company, in laying plans for their 220,000-volt lines, running from Pit River to the San Francisco district, have likewise provided high-voltage circuit breakers and relays so as to give automatic operation in case of line trouble.

The desirability of this automatic breaker operation is self-evident, as it insures a maximum speed in the clearing of troubles and a minimum loss of service. With two parallel circuits there should be no interruption of power at the receiving end, under any circumstance, unless both lines are simultaneously in trouble. Operation of the more moderate voltage lines, in various parts of the country, has demonstrated that dependable relay operation for the automatic opening of circuit breakers is obtainable.

The problem confronting the engineers, in carrying out this method of operation, is therefore largely the design and manufacture of circuit breakers which would successfully handle the rupturing capacities required on these high-voltage lines. Such design and manufacture has been carried out and the circuit breakers for this service are now installed. In carrying out the design, it is noteworthy that no radical departure was made from the construction used in breakers for more moderate voltage service.

Circuit breaker tanks have been made larger and heavier in order to give the greater clearances required by the high voltages and to care for the heavy rupturing capacities called for. The actual contact parts for the 220,000-volt circuit breakers are practically identical with those of the larger moderately high voltage breakers. Solenoid operating mechanisms energized by direct current are employed in both types of breakers.

Bushings, for carrying the high voltage into the breaker tanks, are a continuation of the standard lines of design, both condenser type and the oil-filled type of bushing now being in service at 220,000 volts. All of the bushings have been made of the outdoor type with porcelain shields provided to protect against the weather. Bushing-type current transformers provide means for current measurement and relay protection. The bushings are made interchangeable with transformer bushings for the same voltage service and the insulation tests on breakers have been brought into line with the reduced tests on transformers, arrived at by consideration of the effect of the solidly and permanently grounded neutral of the system.

It has been necessary to determine the rupturing capacities of these high-voltage circuit breakers by calculation from certain determining data such as the strength of tanks, the amount of oil, the depth of the contacts under the oil and the speed of moving parts or arc extinction and up to the present it has not been possible to make actual tests of these rupturing capacities.

Such tests, however, have been made on the similarly designed breakers used on 110,000-volt circuits and these tests have contributed empirical data which gave assurance that the 200,000-volt circuit breakers will take care of the rupturing capacities specified. These rupturing capacities are considerably in excess of any current which they may be expected to be called upon to open until the systems on which they have been applied have grown still larger and more generating capacity has been installed.

DOLOMITE FOR REFRACTORIES

Research work on the utilization of dolomite in refractories is being continued by the Department of the Interior at the Ceramic Experiment station of the Bureau of Mines, Columbus, Ohio. The main problem being studied is to combine the lime in the dolomite so that it will be nonslaking and at the same time hold up the refractories, thereby rendering available abundant deposits of dolomite for extensive use as a basic refractory. Work previously done by the Bureau of Mines on different fluxes for rendering dolomite refractories non-slaking indicated that by careful selection and preparation, refractory bricks could be made, one of the best fluxes tried being alumina-iron flux. More recent work done by the bureau consisted of slaking time tests on varying proportions of dolomite mixed with an alumina-iron flux. The porportion of flux to dolomite was varied between 5 and 20 per cent. The refractory properties as well as the slaking tendency of these mixes was studied. After the best proportion of flux to ground rock was determined, bricks were made by the soft mud and dry press processes, using both organic and inorganic binders. Then methods of firing to produce sound bricks were studied. As a result, a composition has been found which, when compounded with the proper binder and burned after a given procedure, produces a strong, nonslaking brick of high refractoriness. The bricks are satisfactory in every respect, except that uniform shrinkage has not been completely attained. During the coming year, bricks will be produced and tried out in the industry.

Gaseous Ionization in Built-up Insulation--II

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Review of the Subject:—*It has been suggested frequently that the failure of high-voltage armature bars might be due to deterioration caused by gaseous ionization in entrapped air spaces. In an earlier paper a series of tests on a number of 6600-voltage mica folium armature bars made up with different degrees of mica content was described. The variations of the dielectric losses with voltage and with temper ture were studied and by means of the application of pressure it was shown to what extent losses due to internal ionization were present. The influence of these ionization losses on the life of the bars was also studied.*

The tests of the foregoing paper are continued in the present paper, extending to a wider range of type of armature insulation. The general results are as follows:

1. The absolute values of loss due to internal ionization in well constructed armature bars are small compared with dielectric losses of other types.

2. The losses due to internal ionization do, however, cause a progressive deterioration of the insulation. This is shown by a gradual increase in the loss and power factor of the insulation.

3. It is indicated that the principal function of mica in this type of insulation is in the reduction of the conductivity of the insulation and the withstanding of the action of internal ionization. The indications are that full mica folium content can be safely reduced only by use of the best grade of mica folium and the best conditions of application without variation. Several bars having relatively low mica content have compared favorably with those having the maximum mica content, indicating reliable insulation over long periods. It appears that high mica content is necessary in order to maintain a high factor of safety to cover the variations in factory processes.

4. In the drying out period this type of insulation is subject to great danger from relatively brief periods of application of voltage. During these periods the losses are high, internal temperature is raised, with further increase of loss, leading to breakdown. The greatest increase of loss in this danger period is in the range 25 deg. to 50 deg. cent.

5. The drying out period at 125 deg. cent. and during which normal voltage may not be applied to the insulation for more than a minute or two, varied in the specimens studied from fifteen days to three months.

In a foregoing paper, under the above title, a series of tests has been described, investigating the presence of gaseous ionization, or corona, in various types of armature insulation, with particular reference to its magnitude and its influence on the life of insulation. It was shown that the magnitude of the power loss due to ionization is relatively small, as compared with the dielectric loss due to other causes. It was shown that under sustained voltage and temperature the loss in those bars which initially had the highest ionization loss, increased gradually, indicating a progressive deterioration of the insulation due to these causes. These life tests were made on bars No. 33, 46 and 49; the two former having standard 6600-volt mica folium insulation, and the last a slightly smaller proportion of mica.

In the present tests the study of the progressive changes in the internal loss is continued, the principal purpose in view being to investigate the influence of varying degrees of mica content in two groups of bars, one having paper, and the other treated cloth, as the supporting binder for the mica folium. A description of the make-up of the various bars is given in the foregoing paper.

The general outline of the present tests is indicated by the following list of the bars tested. The list includes the bars upon which report has already been made as indicated. The remaining bars have been selected as having decreasing amounts of mica, and as having the greatest percentage corona loss in their respective groups. However, in two groups of paper bars no bar showed a corona loss higher than 2 per cent.

To be presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

Thus as regards the influence of corona, No. 39 is the most conspicuous new case in the paper group.

TABLE I.

Paper Insulation	Cloth Insulation
No. 33—full mica folium (92 per cent) 14 per cent corona loss—already studied	No. 46—full mica folium (no cloth) 92 per cent, 3 per cent corona—already studied
No. 36—70 per cent mica folium 2 per cent corona	No. 49—73 per cent mica folium 37½ per cent corona—already studied
No. 39—50 per cent mica folium 14 per cent corona	No. 54—42 per cent folium 28 per per cent corona
No. 41—28 per cent mica folium 2 per cent corona	No. 55—22 per cent mica folium 32 per cent corona
	No. 60—0 per cent mica folium 14 per cent corona

Bars 36, 39 and 41 were placed in one oven and Nos. 54, 55 and 60 in a second duplicate oven. These ovens were of the Fries type and were electrically controlled up to about 135 deg. cent. maintaining temperature constant to about 2 deg. in the upper range. In the tests the temperature was raised by steps lasting several days each, to a maximum of 125 deg. cent. The ovens were equipped with high-voltage bushings and 10-kv. was applied for 16 out of every 24 hours continuously, to the central conductors on the sample bars. Other leading-in bushings afforded connections to the central test electrodes and to the guard ring electrodes on each bar. At stated intervals the voltage was interrupted and measurements made of dielectric loss and charging current at 7.5 kv. and also of insulation resistance as based on application of continuous voltage for one minute. The alternating frequency was 60 cycles. Other conditions surrounding the methods of measurement are described in the earlier paper.

Experimental Results

The general results of the tests may be seen in Fig. 1, which gives the record of continuous observation on the

bars mentioned, subjected to continuous temperature over a period of ten months. The continuous application of voltage was possible over a period of six months only, on bars Nos. 36, 39 and 41, and not at all on Nos. 54, 55 and 60 for reasons described below.

Before beginning the temperature run the losses in all of the bars were measured at atmospheric temperature, and the values compared with those taken one year previously, when the measurements, described in the earlier report, were taken. The values of loss in bars Nos. 36, 39 and 41 were found to be practically unchanged indicating no alteration on standing idle at temperatures in the neighborhood of 25 deg. over a period of one year. On the other hand, the bars of the cloth group showed increases in loss as follows: No. 54—15 per cent; No. 55—6 per cent; No. 60 (no values permitting the application of voltage over reasonable periods of time. The continuous application of voltage was possible only after 3½ months, on the bars having the larger percentage of mica, and on two of the bars low in mica it was never possible, as described below. During the initial period, therefore, measurements were made only on bars Nos. 36 and 54 as pilot bars for their respective groups.

Internal Losses

Referring to Fig. 1 the sharp increase in dielectric loss following the increase in temperature is at once evident by the rise between 24 deg. to 42 deg.; the losses in each of the bars 36 and 54 are practically doubled. There is little change in the loss at this temperature and on increasing to 63 deg. there is a further increase

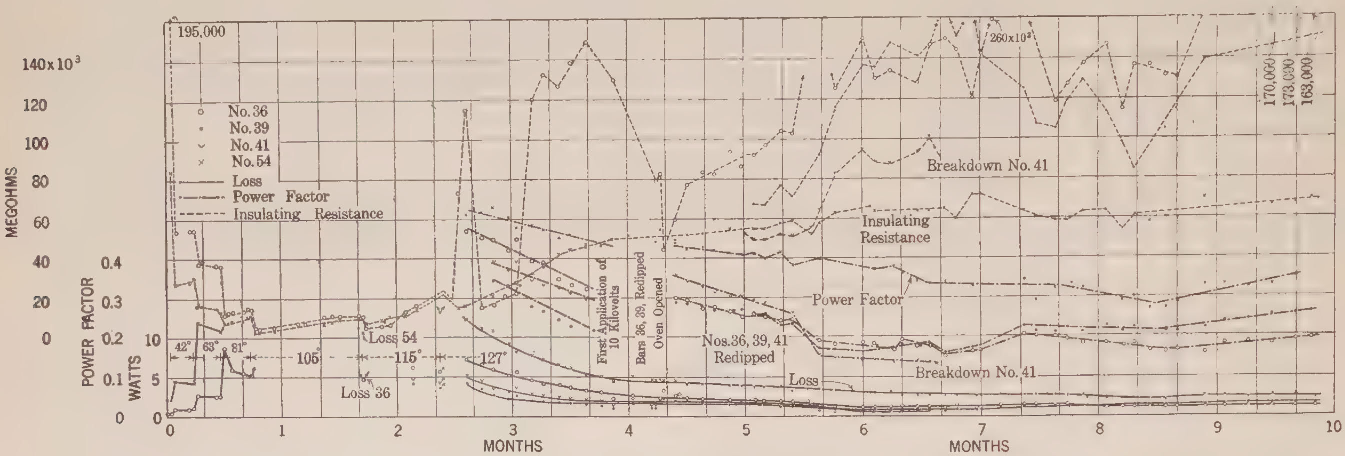

Fig. 1—Losses in Armature Insulation at High Temperature and High Voltage

mica)—40 per cent; thus green bars having cloth as a supporting binder show a tendency to increase their internal losses with age. Absorption of moisture suggests itself as the most probable cause of this increase.

After assembling in the ovens the bars were first measured at atmospheric temperature 24 deg. cent. The temperature was then raised to 42 deg. for 6 days, then to 63 deg. for 7 days, then to 81 deg. for 8 days, to 105 deg. for 29 days, to 115 deg. for 20 days, and finally to 125 deg., at which value it was held continuously. The duration of the run at each temperature was determined solely by the behavior of the insulation as regards its internal loss. Every elevation of temperature was followed by a marked increase in the internal loss, the value of the loss thereafter decreasing at various rates. During the later increases of temperature the losses increased so sharply as to make it impossible to apply voltage continuously, as breakdown would follow after very short intervals. In fact, above 81 deg. it was found inadvisable to apply the measuring voltage of 7½ kilovolts over the period of 8 minutes, necessary for the measurements, for fear that breakdown would occur. It was only after two months, and after the insulation had been subjected to 115 deg. for sometime, that the losses had fallen to of loss by about 2½ times. At sustained 63 deg. there is a tendency to a decrease of loss. On raising the temperature to 81 deg. the voltage cannot safely be applied to No. 54, and No. 36 shows an 18-fold increase of loss over its initial value. At 81 deg. however the loss falls off fairly rapidly, although it increases again sharply when the temperature is raised to 105 deg. From this point onward for a period of nearly two months, it was not possible to make complete loss measurements owing to the high values of loss. The conditions of the bar could be told by a brief application of voltage in its effect on the wattmeter reading. A slowly increasing wattmeter indicates internal heating of the bar, and the danger of the continuous application of voltage. Isolated readings are shown toward the end of the second month. A regular program of loss measurements was begun after about two and a half months, when the bars had been raised to 125 deg. cent. and maintained at that temperature for several days. During this early period regular readings of insulation resistance were possible, and these also afforded some information as to the condition of the insulation. Comment in this connection is made below.

Bars Nos. 55 and 60 after their initial reading at atmospheric temperature would at no time stand 7½

kv. for a period sufficiently long to obtain the loss measurement. They showed a rapid increase in wattmeter readings and when subjected to voltage on January 26th, after nearly three months, No. 55 punctured under this test. In the earlier report several curves are given showing the increase of internal loss under the continuous application of potential. In Fig. 2 herewith is shown this effect as applied to bar No. 56 of the same group as No. 55 taken at atmospheric temperature. For the same reasons, although the regular loss measurements on the remaining bars began at two and one-half months, it was not possible to apply 10 kv. continuously to them until well on to the end of the third month. For example, No. 54 early in the third month showed an increase of 25 per cent in its internal loss in a period of 20 minutes.

It is noteworthy that in the present tests this initial period of high loss and unstable condition, often referred to as the drying out period, extended over a period of four months, whereas in the tests of the earlier report, having to do with insulation having high mica content, this period was limited to only about 15 days. While the losses were somewhat high after that period they were still sufficiently low for measurement, and as to cause no steady rise due to internal heating. In fact, comparing the results of the present tests with those on the bars having higher mica content, we find that the initial rises of loss with increasing temperature are less for the high mica bars and of shorter duration. After one month all three high mica bars show less than 3 watts each at 110 deg., while after two and one-half months the low mica bars are at from 3 to 12 watts each at the same temperature. The low mica bars dried out much more slowly and approached constant values at six months as against two and one-half months for those high in mica. Note, however, that the final constant minimum values of low mica bars (0.6 to 1.25 watts) are only slightly higher than those high in mica (0.6 to 1 watt).

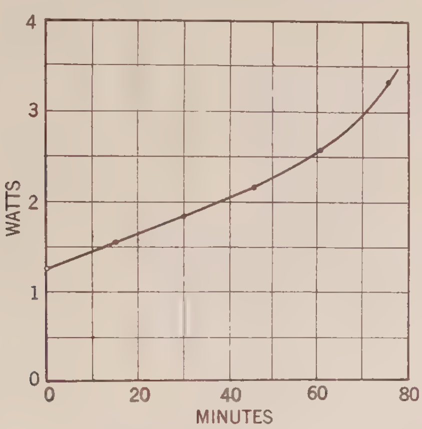

Fig. 2—Loss-Time, Bar 56, 7.5 kv.

The conclusion from these facts is that in some way the presence of mica affects not so much the ultimate values of the dielectric losses themselves, but the way in which they change when subjected to temperature. Observations on the values of dielectric absorption for this type of insulation give indications that the major proportion of the dielectric loss is due to absorption. Consequently, the variation in behavior between high mica and low mica insulation with time, will probably be found to lie largely in the variation of dielectric absorption.

The regular decrease in values of loss under continuous high temperature, as indicated in Fig. 1, begins toward the end of the second month. Toward the end of the third month 10 kv. was applied to the bars for 16 out of each 24 hours, together with the sustained temperature of 125 deg. cent. These conditions were continued until the end of the test. Occasional irregularities in these curves were caused by temporary fluctuations in temperature, and on two occasions it was necessary to open the ovens and re-dip one or more bars in insulating compound. This insulating compound was necessary to prevent surface discharge between the exposed end of the central conductor and the measuring electrodes. It will be observed, however, that even at these points of irregularity in the curves the relative values of the losses in the several bars remain approximately the same.

Considering the results plotted in Fig. 1 we may note as follows:

Of the six bars investigated only three, Nos. 36, 39 and 54, survived the test of ten months of high temperature and continuous application of voltage.

Bar No. 36, 70 per cent mica folium and 2 per cent corona, shows throughout a very low value of loss. In the earlier stages this loss was slightly higher than those of No. 39 and 41 although the three had much the same value of loss in the sixth month, when No. 41 broke down. After seven months No. 36 had the lowest loss and lowest power factor and remained in this position until the end of the run, showing, therefore, best prospect for long life. No. 36 started with the lowest initial corona loss and its good showing at the end of the test is in accord with the results of the tests described in the earlier paper, in which the bar showing least initial corona loss, showed in the final stage lowest total loss and best prospect of long life.

Bar No. 39, 50 per cent mica folium, 14 per cent initial corona, shows throughout a very low value of loss. During the seventh month, however, its loss gradually rises above that of No. 36, its insulation resistance falling at the same time. This increase in loss is attributed to the presence of internal ionization in No. 39, and its gradual influence in causing deterioration of insulation. The effect is also seen in the curves of power factor.

Bar No. 41, 28 per cent mica folium, 2 per cent initial corona. This bar is especially interesting because notwithstanding its low mica content it showed from the beginning a very low value of loss, this value being comparable with that of Nos. 36 and 39 after four

months. This low value of loss was maintained for six and one-half months, when unfortunately the insulation punctured. The breakdown occurred to a guard ring electrode, and so the approach to the breakdown condition was not observed on the instruments. The final low value of loss of this bar is the same as that obtained in bar No. 46 of the first report, which had full mica folium content, and which showed the best performance in the earlier tests. The low loss in No. 41 is significant as showing that low mica content may under some conditions give as good characteristics as high mica content. It appears that No. 41 must be regarded as an exceptional case in which a relatively low mica content, well preserved, after careful application, results in good electrical characteristics which, however, can hardly be considered as typical in view of the history of other low mica bars. In fact, as stated, this bar broke down after six months.

Bar No. 54, 42 per cent mica folium, 28 per cent corona, is the only bar in the cloth group surviving to the final period. It shows a relatively high loss which is to be attributed rather to its low resistance (*i. e.* high absorption) than to its high initial value of corona. There is little, if any, evidence of increase of loss in the final stages. However, it is to be noted that on account of its high total loss it was not possible to submit this bar to continuous high voltage. Therefore, it offers no conclusion as to the influence of internal ionization on its life.

Bars Nos. 55 and 60 never reached a stage at which voltage could be continuously applied. Both of these bars had high loss at atmospheric temperature, preventing power measurement for sometime after their temperature was raised. No. 55 broke down at the end of two months, at 115 deg. cent. during an attempt to measure its power loss. At the start at atmospheric temperature the resistance of No. 55 was 6500 megohms, and that of No. 60 340 megohms, showing the very great influence of the mica in No. 55. Two months later at 115 deg. No. 60 showed 16.5 megohms which, however, rose under sustained temperature to 47 megohms in another month, and 236 megohms in four months. These bars were then removed from the oven to make room for the others. No. 60 is interesting in several ways. In spite of its very low insulation resistance when cold it had the relatively low value of loss of 5.35 watts. Dielectric absorption in No. 60 is completely masked by its high conductivity. The value of insulation resistance given above is determined from a one minute reading at continuous potential, but this value remains practically unchanged over one-half hour or more. The value of resistance so computed, however, accounts for only 16 per cent of the total dielectric losses. Although the absorption is masked it is present, as is shown in another section of this report, and we have here clear evidence of the importance of dielectric absorption as distinct from conductivity in causing the losses in dielectrics.

Insulation Resistance

The curves of insulation resistance in Fig. 1 are plotted from observations with continuous potential in the neighborhood of 200 volts, and current in a high-sensitivity galvanometer. The galvanometer reading was taken at exactly one minute after the application of voltage. The insulation was then short-circuited one minute and a galvanometer reading with reversed voltage at the end of another minute again taken. The mean of these two readings was used in computing the resistance. As is well known, the value so obtained does not represent the true ohmic resistance but merely gives one point on the absorption curve. In many cases and particularly in some of the bars under observation, a steady reading of the galvanometer only results after a long period of time, say one hour or more. It often happens that the one minute reading is many times greater than the final approximate steady value. However, except under conditions in which the shape of the absorption curve is materially altered, the proportionate relation between the one minute and final readings remains constant under a variety of conditions. While, therefore, the curves in Fig. 1 do not give, as suggested, the final values of resistance, they do represent in their mutual relation the relative changes in the final resistance of the several bars. They probably represent more exactly the relative values of the absorption, since the one minute reading is in most cases well up on the initial steep portion of the absorption curve. In taking this point of view it should be noted that high values of insulation resistance indicate low values of dielectric absorption and vice versa. It is highly probable that the major portion of dielectric losses are due to absorption, and it is for this reason that there is a fairly uniform relation between the so called insulation resistance curves and the loss curves. The relation, however, is total loss and absorption, rather than loss and final ohmic resistance. Referring then to the insulation resistance curves, it will be seen that at atmospheric temperature they indicate a very high value of resistance and that this resistance decreases very sharply when passing from 24 deg. cent. to 42 deg. cent. The decrease here is much greater than in any other of the successive temperature steps leading up to 125 deg. cent. It is especially significant that absorption should be relatively low in the green state of insulation, at room temperature, and be greatly increased by a slight elevation of temperature. This moderate elevation of temperature leads to a condition of high absorption, low resistance, and high loss extending over a period of two or three months. If this change of condition is due to the presence of moisture, which is the only influence which suggests itself, would it not be possible to assemble and apply this insulation at 40 deg. or 50 deg. cent. and so avoid the low dielectric strength of the weak period, and also its long duration? Under the influence of higher temperatures, the insulation resistance after a time begins to rise again, gradu-

ally increasing in value and being accompanied always by corresponding decrease in the values of loss. The readings of the galvanometer in these regions of high resistance become quite erratic and apparently the condition of the insulation as regards resistance and absorption is in a continual process of change. For example, the readings immediately following the removal of the alternating test voltage (10 kv.) from bar 36 will be quite different from those taken 15 minutes later. The first application of high alternating test voltage evidently causes some shake up in the structure of the insulation, and it is followed by a change in the value of the insulation resistance. The opening of the oven for a brief period may also be followed by changes in this quantity. Expansion of the sides of the bars,

Under sustained high temperature the insulation on the flat sides of armature bars tends to expand forming a curved, instead of a flat surface. This obviously causes increase in the thickness or number of the enclosed air spaces, resulting in a decrease in loss in the low-voltage range, and a greatly increased loss if the voltage is above the ionizing value for the entrapped air or gas. This expansion also causes a loosening up of the structural rigidity of the insulation, probably causing the shifting of mica, and so further increasing the likelihood of failure. The expansion of the insulation in the present tests is undoubtedly greater than could occur in the slot of a generator armature, but even in the latter case the assembly clearance provides space for some expansion. It is, therefore, important

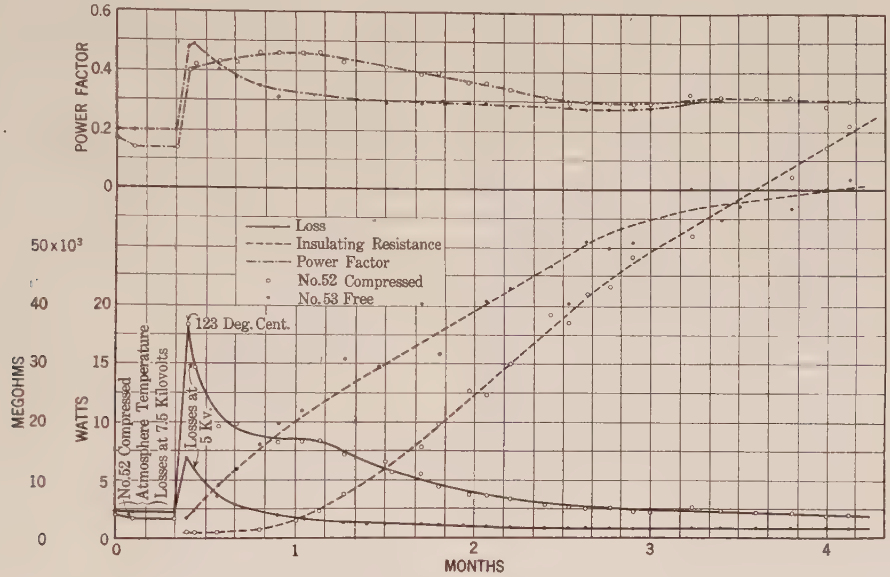

Fig. 3—Losses in Armature Insulation Influence of Compression and Temperature

particularly those containing mica, following long periods at high temperature, lead to thicker air layers, a high resistance, and also probably to unstable mechanical structure. The insulation resistance curves, therefore, in their regular progress are to be regarded for the light they throw on the variation in dielectric absorption. In their upper erratic ranges, however, they give evidence of little else than unstable internal condition. See Appendix A.

Influence of Compression

Since internal ionization takes place in entrapped air layers, compression of the insulation should reduce the volume of these layers, or increase the density of the entrapped gas, and so reduce the loss due to ionization. At the same time pressure will reduce the total thickness of the insulation, and thus increase the voltage gradient and the losses in the solid parts. In the earlier paper it was shown that in far the greater number of cases the reduction of the ionization greatly offsets any increased dielectric losses, and that an increase of loss on compression appeared in only two bars out of 30 investigated, and in each case the increase was very small.

to know whether a solid structure under compression, reducing the internal gaseous ionization, and maintaining fixed position of all interior layers, would result in longer life for the insulation.

For test of this question bars No. 52 and No. 53 both of the same structure (treated cloth and 42 per cent mica folium) were used. The insulation under the electrodes of No. 52 was tightly compressed with steel plates and screw clamps, that on No. 53 being left free. Each was dipped in insulating compound to prevent surface leakage and the two set up in one of the constant temperature ovens, at 125 deg. cent., replacing No. 55 and No. 60, withdrawn for reasons described above. The continuous record of this test is shown in Fig. 3. The loss measurements at atmospheric temperature were made at 7.5 kv. Those at higher temperatures were made at 5 kv. instead of 7.5 kv., since in the early stages the losses at 7.5 kv. were so high as to endanger the insulation.

Referring to Fig. 3, the initial readings were taken at atmospheric temperature and with no compression on either bar. The readings of the second day were

taken with No. 52 firmly compressed as described and No. 53 free, both at atmospheric temperature. An 8.5 per cent reduction of the losses in No. 52 is evident. This reduction is due to the decrease in the loss due to internal gaseous ionization. These readings were repeated a few days later and the bars were then dipped and placed in the oven and their temperature raised to 123 deg. cent. This rise in temperature is accompanied by the usual sharp increase in dielectric loss, and increase of absorption, *i. e.*, decrease in insulation resistance. It is especially interesting to note that the increase in the loss of bar No. 52 under compression is very much greater than that of the free bar No. 53, in spite of the initial lower values of the former. This immediately suggests that the compression of the insulation greatly retards the drying out process. This bears out the conclusion reached in the foregoing section of this report, that the greater part of the reduction in insulation resistance, or the increase in absorption, takes place during the first stage of temperature rise, and also takes place quite rapidly. Whatever the process of drying out may be, such as the driving out of water, it is apparent that it is seriously retarded by the compression of insulation. The insulation resistance curves also clearly indicate this condition. Immediately following the sharp decrease in resistance attendant upon high temperature, the resistance of No. 53 begins to rise rapidly while that of No. 52 remains practically stationary over several days and begins to rise quite slowly. The further history of the bars over the period of four months shows that No. 53 maintains its lower value of loss but that of No. 52 is gradually approaching it. It is to be borne in mind that the values of loss shown by these curves are taken at 5 kilovolts, at which voltage the losses of internal ionization are very low. It would appear that No. 52 should ultimately fall below No. 53 since it was lower at the start. The tendency of the insulation resistance curves indicates this more definitely than do the loss curves. It will be noted that in the final stages the resistance of No. 53 is increasing less and less rapidly, while the rate of increase of the resistance of No. 52 is rising more rapidly and, therefore, tending to higher values than that of No. 53. Apparently, however, considerable further time would be necessary to bring the two bars to their final constant values of loss. Unfortunately the work was of necessity interrupted before it was possible to apply continuously, the normal operating voltage on these bars, and to continue observations on them so as to make a relative study of their life histories. It would appear that a continuation of tests of this character should give important information as to the influence of ionization and compression on the life of this type of insulation. See Appendix B.

Conclusions

From the results of the life tests as shown in Fig. 1 we conclude as follows:

1. The conclusion in the earlier paper that internal ionization increases the dielectric loss and tends to shorten the life of built up insulation is supported by the results of the present tests. In each group in which comparison is possible the longest life is associated with low corona loss. In the two groups, highest and next to highest mica, the bars having high initial corona loss, at the end of the test, show evidence of gradual deterioration as compared with steady conditions in the bars initially showing low internal ionization.

2. Considering in general the influence of the amount of mica content: In the earlier test the best showing was made by a full mica (92 per cent) bar (No. 46). In the present test the best showing is made by a second group bar, No. 36 (70 per cent mica folium), and No. 39 (50 per cent mica folium) a third group bar is also still in good condition at the end. Moreover, No. 41 (28 per cent mica folium) made a run of six months with very low losses. These, however, are the only ones in which a relatively low content of mica folium gives a performance approximately that of full mica folium content. Note for example that No. 54 (42 per cent mica folium) and No. 55 (22 per cent mica folium, were not in condition after ten months drying out to stand the constant application of voltage. Throughout the course of both series of tests there have been a number of instances of high internal loss and heating and several cases of breakdown. These cases for the most part have been found in bars of the third group, or below, that is, those having less than 70 per cent mica folium content.

3. In general the indications are that the principal function of mica is in the reduction of the conductivity of the insulation, and in withstanding the action of internal ionization. While definite conclusions are scarcely permissible from the small number of bars tested, the indications are that the full mica folium content can be safely reduced only by insuring the best grade of mica folium, and best conditions of application, as regards uniformity and compact structure, these conditions being maintained to a high degree in continued factory production. Several bars having relatively low mica content have compared favorably with those having the maximum mica content. They are relatively few, however, in the total number studied. It appears that high mica content is necessary in order to maintain a high factor of safety to cover the variations in factory process. On the other hand, it has been shown that under best conditions considerably less than the full mica content may yield reliable insulation.

4. In the present tests the drying out period is much longer than that of the earlier tests, and the increase of loss with increase of temperature, much greater. The average mica content was higher in the earlier test, although in one case bars of the same group showed the difference noted. The greatest step in the

increase in loss and decrease in insulation resistance occurs in the change from 25 deg. to 50 deg. cent.

5. An uncompleted study of the relative performance of compressed and free insulation, indicated that the former passes through a more dangerous drying out period, but ultimately approaches equality with the free bar. From then on it should show superiority owing to the higher internal ionization loss in the free bar. This test should be continued.

Appendix A

Insulation Resistance

Irregularities in the one minute galvanometer readings for insulation resistance have been attributed, in the foregoing, principally to a continuous process of alteration of the structure of the insulation under sustained high temperature and high voltage. The matter has been studied further, and apparently the principle influence in causing the variation in the galvanometer readings is the residual or absorbed charge in the insulation, resulting from the sustained alternating voltage which was interrupted only for the brief intervals required for loss and insulation resistance measurements. A series of continuous charging current observations was taken on bar No. 56 immediately following the interruption of the 10-kv. alternating voltage, 30 seconds being required for the change of connections. Right and left galvanometer readings one minute after the application of the continuous voltage, and with one minute short circuit in between, showed great irregularities. The values of the readings in either direction, and the relative values between right and left readings, varied widely. Thus in two successive observations the right and left readings were 6 and 8, and 12.5 and 6 mm. respectively, at 285 volts d-c.

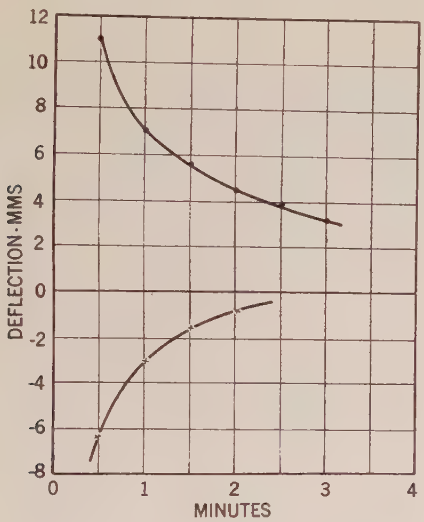

Fig. 4—Residual Charge After Alternating Voltage

A series of discharge curves was then taken. As promptly as possible after the removal of the 10-kv. alternating, bar No. 36 was connected for discharge through the circuit used for insulation measurements (see former report) the resulting deflections were right and left without regularity, and the curve showing the change of deflection with time has the characteristic form of the discharge of dielectric absorption. Fig. 4 shows two of these curves one of right and the other of left hand deflection. These curves, surviving after a 30-sec. interval necessary after interruption of the alternating voltage, but of irregular initial value and polarity, show clearly the residual absorption due to the foregoing alternating voltage. In the course of the life tests the insulation resistance measurements were taken sometimes immediately after interruption of the alternating voltage, and sometimes after the power measurement, and without regulation of the time interval following the removal of the alternating voltage. Hence it seems clear that the variation in the values of insulation resistance is in large measure due to this cause.

Appendix B

Influence of Compression

It is significant that towards the end of the run of Fig. 3, bar No. 52, under compression, is tending to a lower power factor, and a higher insulation resistance than No. 53, and that its loss is still falling while that of No. 53 is about constant. If continued with the application of sustained high voltage this test probably would have shown next a decreasing resistance and an increasing loss for No. 53 due to its internal ionization. The original ionization loss in bar No. 53 was about 25 per cent, that or No. 52 at the beginning of the present test being considerably less, and reduced to a minimum by heavy compression.

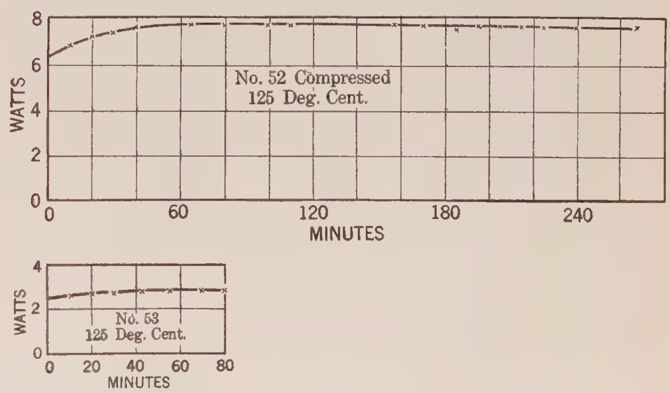

Fig. 5—Influence of Continued Application of Voltage on Dielectric Loss

Fig. 5 shows the results of a continuous run for a few hours at 10 kv. on both these bars to determine whether they were ready for the continued application of alternating voltage. It is seen that there is no increase in loss in either case after the first hour and thus that the internal losses are dissipated as fast as generated. The initial greater rise in loss in No. 52 is due to the elevation of internal temperature due to its greater losses. It is unfortunate that this run was of necessity interrupted at a time when the bars were just ready for studying the influence of voltage and internal ionization.

Alkali Vapor Detector Tubes

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Review of the Subject:—*This paper describes unusual and very desirable results that are obtained on priming tungsten filament three-electrode vacuum tubes with an alloy of potassium and sodium when such tubes are used as detectors of radio frequency currents in receiving circuits.*

The method of preparing the tubes and of introducing the alloy is described in some detail.

Data obtained for these alkali vapor tubes are shown in the form of curves. They show the static characteristics of the tube, the operation characteristics when used as detectors, also the effect of filament temperature increase upon their performance.

The results obtained when the tubes are used as detectors include—lower optimum plate voltage (5 to 10 volts), less critical adjustment of plate voltage, steady action, considerably greater sensitiveness to weak signals than for gas content tubes, and no distortion in detector action.

CONTENTS

I. Introduction

About two years ago the authors of this paper completed an experimental investigation on the effect of various residual gases in three-electrode vacuum tubes upon the characteristics of the tubes and upon their performance as detectors and demodulators. It was found that the introduction of certain gases

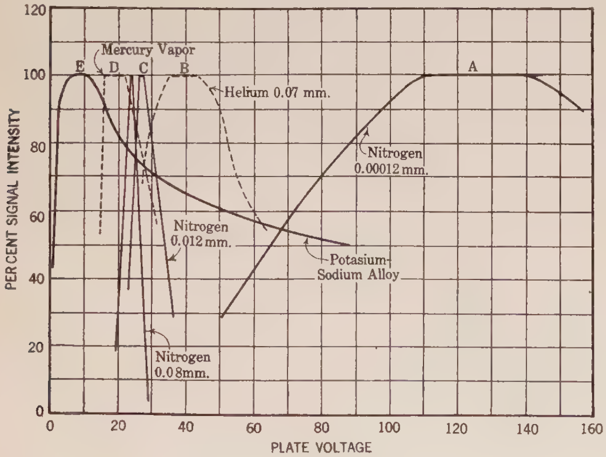

Fig. 1

improved to some extent the sensitivity of the tubes as detectors.[1] Argon at a pressure of 0.005 mm. of mercury gave the best results. The most important result of this earlier investigation was the effect of gases upon the critical characteristics of detector tubes. The data relating to these are summarized in the form of curves in Fig. 1. The curves show how critical the adjustment of plate voltage becomes for air, nitrogen, neon, etc., when the pressure within the tube is increased. Helium, having a higher ionizing potential than the gases just mentioned, causes a detector tube to function best at a corresponding higher plate voltage. It should be noted also that mercury vapor, due to its lower ionizing potential, causes a tube to function best at correspondingly lower plate voltages. However, at the same time the allowable per cent variation of plate voltage for mercury vapor with no change in audibility was found to be greater than for the other gases except helium. Furthermore, if the pressure of the residual gas is increased the plate voltage required for the best audibility of signal response, which will be called the "operating voltage," was found to vary as shown in the curve of Fig. 2. Hence it was concluded that if a gaseous medium possessing an extremely low ionizing potential could be provided the tube would function as a detector on a minimum plate voltage.

The characteristic of mercury vapor shown in Fig. 1 indicates that a metallic vapor possessing a very low ionizing potential would not only operate on low plate

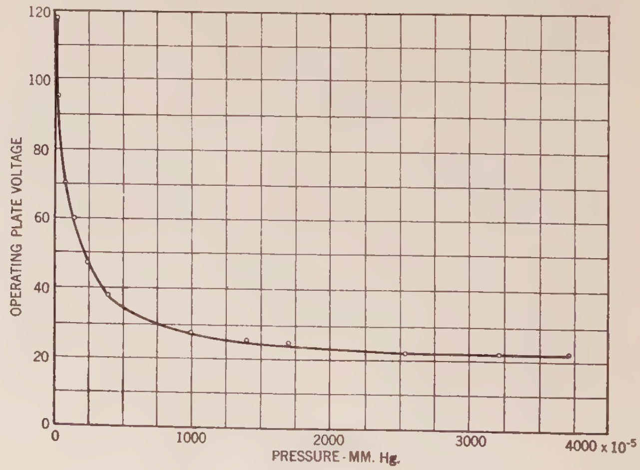

Fig. 2

potentials but also would not be critical as regards plate voltage adjustments. Vapors of certain alkali metals, and also of certain alloys of these metals, have very low ionizing potentials. Notable among these is the alloy of potassium and sodium, the vapor of which has an ionizing potential of 4 volts or less. Accordingly, a small amount of this material was introduced into several vacuum tubes by methods described presently. Curve *E* of Fig. 1 is typical of the results

To be presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

1. *Phys. Rev.*, 19, (2), No. 3, 1922.

obtained. Curves similar to this one will be shown later. In addition to this other results were obtained, which were entirely unexpected, and will be described in due course.

II. Method of Priming Tubes

Standard types of detector and amplifier tubes, and also special forms made in this laboratory, were primed with a molecular alloy of potassium and sodium. This alloy which at ordinary temperatures is a fluid resembles mercury in appearance though its density is less than one. The potassium-sodium alloy was contained in an evacuated glass supply tube A, Fig. 3. Two or more three-electrode tubes were fused in a vertical position onto a horizontal manifold as shown in the figure. This manifold was connected through a T-tube, one branch of which, B, led to the evacuating system, and

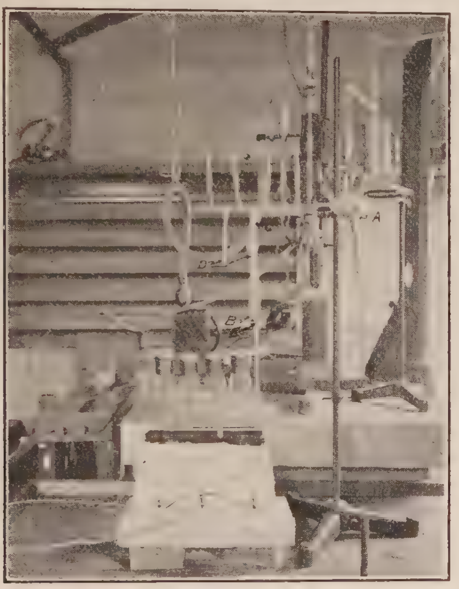

Fig. 3

the other to the K-Na alloy supply tube A. The evacuating system consisted of a charcoal tube in liquid air, a phosphorous pentoxide tube, a mercury vapor trap also immersed in liquid air, a McLeod gage, a mercury condensation pump, and a rotary supporting oil pump. The supply tube, A, had a number of branch outlets, each branch being drawn down into a slender tube D, and also provided with a constriction, for the introduction of the alloy into the manifold and for subsequent sealing off. Connection between the outlet tube and manifold was made by heavy walled rubber tubing lubricated with rubber cement and tightly wired down, as shown in the figure.

When the pressure was of the order of 10^{-4} mm. of mercury the tip at D, which was previously nicked with a file, was broken off by bending sharply the rubber tubing. The evacuation was continued and in order to completely as possible outgas the tubes the filaments were kept incandescent, and also 150 volts were applied to the plates. This outgassing process was continued until the electron tubes (having been previously connected to receiving circuits) functioned best as detectors with 60 to 80 volts on the plates. This test indicated that the tubes were fairly well outgassed. The supply-tube A was now tilted up and a little of the alloy was allowed to run down into the manifold, after which tube A was sealed off at C. To guard against possible leaks, due to the rubber connecting tube, another seal off was made at E.

The oil bath with its electric heater attached was now raised so that the horizontal manifold was immersed in the oil. The bath was gradually heated, with the pumps going, and ultimately the temperature was pushed to about 230 deg. cent., at which temperature the alloy was fully vaporized. The vapor passing through the capillary tubes connecting the manifold to the electron tubes was condensed on the colder walls of the latter forming a thin film, at first of varied purplish hues but shortly becoming silvery white, when viewed on the inside as the deposited film became thicker. Heat coming to the bulbs by reason of being mounted vertically over the oil bath was intercepted by strips of cardboard and by turning on an electric fan. The filaments were kept incandescent at nearly normal filament current during this distillation process, thus preventing a deposit of the alloy on the inner metal parts of the tube, as well as aiding in the process of outgassing. After the inner walls of the bulb were well covered with the alloy the oil bath was removed, and the tubes sealed off. The pressure throughout the final stages of priming was easily maintained at approximately 0.00004 mm. mercury. The presence of the alloy within the tube will "clean up" the remaining traces of air and hence the vacuum improves with time.

It is extremely important to clean all glass and rubber tubing with "aqua regia" and distilled water, otherwise the alloy will stick to the walls of the tubing. The writers preferred to construct new manifolds rather than attempt to clean the used ones, also to use fresh rubber tubing each time. In order to facilitate distillation into the electron bulbs the sealing off strictures should be fairly large—about 1 to 2 mm. inside diameter. Any of the alloy condensed in the stricture should be evaporated gently before attempting to seal off, as excessive heat will burn the alloy giving it a brown color.

The potassium-sodium alloy was prepared by putting potassium and sodium into a glass tube in proportion to their atomic weights, *i. e.*, 39 to 23, the tube was then quickly closed by fusing and the pumps started. Heat was then slowly applied, but not in sufficient quantities to melt the metals until the gage showed a vacuum of the order of 0.001 mm. mercury. The heating was then continued until the metals were melted and thoroughly mixed, after which the flame was removed, the connection to the pumps sealed off, and when cool the mixture was poured through small funnel-like strictures into the previously attached glass supply tube A, which in turn was sealed off, thus providing

a store of potassium-sodium alloy for future use. The alloy must never be exposed to the air.

III. Characteristic Curves

All data and curves shown, with one exception, were obtained with standard Radiotron UV 201 amplifier tubes primed with potassium-sodium alloy vapor.

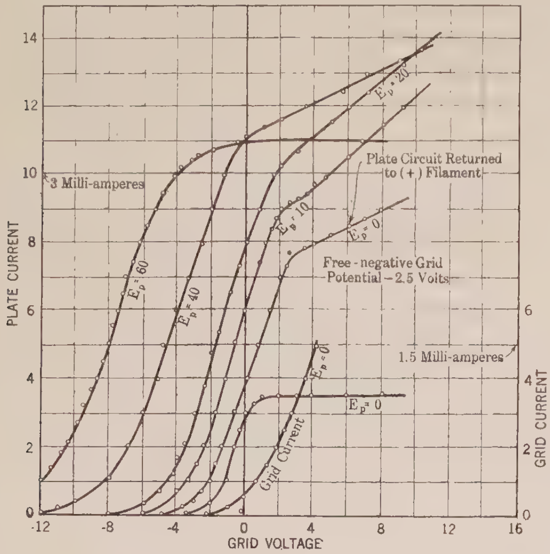

Fig. 4

This type was used because the stock tubes as purchased came with the electrodes carefully freed of gas and hence they required a minimum amount of time in subsequently out gassing. Note is made on all curves, the data for which were obtained for other types

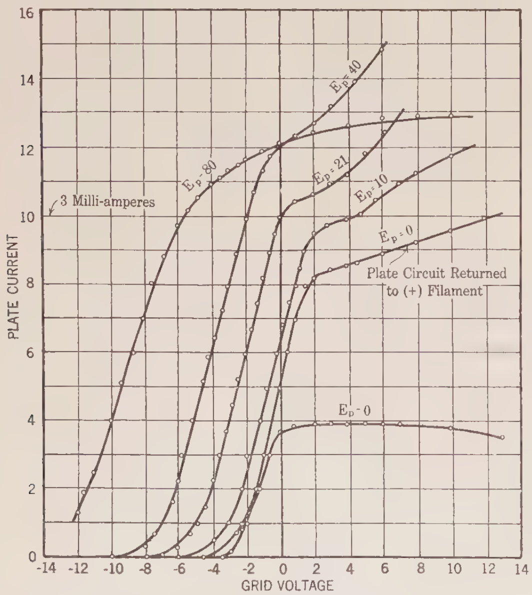

Fig. 5—K-Na Vapor Tube No. 7

of tubes. Figs. 4 and 5 show conventional characteristic curves for different tubes containing potassium-sodium alloy vapor. The vapor pressure in each tube corresponds to the temperature of the coolest portions of the walls. The most remarkable curves are those obtained for zero plate voltage when the plate circuit return was connected to the negative filament terminal, thus making the plate actually negative to a portion of the filament, yet plate currents as high as one milliampere flowed from plate across the vacuum to the filament. This action is the same as though a positive external potential was applied to the plate. These currents at zero plate voltage were 50 to 100 times as great as those obtained for the conventional vacuum or gas content tubes now in use. It should also be noted that the curves are smooth and straight for negative grid voltages, when plotted against plate voltages, and that when a certain plate voltage is exceeded the curves approach a saturation point at negative grid potentials.

If the tube contains a large amount of gas the characteristic humps of gas content tubes are present, how-

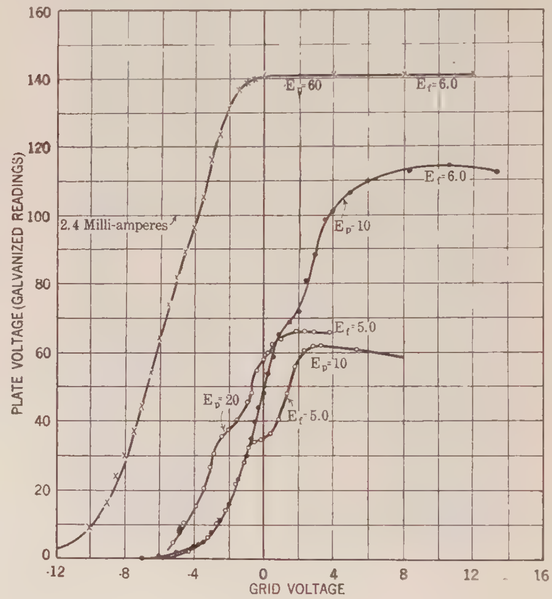

Fig. 6—K-Na Vapor Tube No. 20, Poorly Evacuated

ever, if the filament temperature is substantially increased these humps disappear and the saturation points are not reached until the grid voltages approach positive values. These results are shown in Figs. 6 and 7. With the filament voltage increased from 4.5 volts to 5 volts the curve for 60 volts on the plate remains straight up to 7 volts positive grid potential. In Fig. 8 this same tube was used with the filament voltage increased to 5.5 volts, and with 100 volts plate potential. This indicates that increased filament temperatures make the alkali vapor more active and effective and also that vacuum tubes containing alkali vapor at high vapor pressures possess the characteristics of high vacuum amplifier tubes. At the same time the considerable plate currents that are obtained at low plate voltages, and the steep slope of these low-voltage curves, indicates that the tubes will function as detectors at low plate potentials. This point will be dwelt on later. It was found that to obtain tubes with smooth characteristic curves at normal filament tem-

peratures, and lower, the evacuation must be made as complete as possible, just as in the preparation of high vacuum amplifier tubes.

Grid current curves and emission curves for sample alloy vapor tubes are shown in Figs. 9 and 10, respectively. The high degree of assymetry of the grid-current curves at about 2 volts negative grid potential should be noted. Fig. 11 shows plate voltage-grid voltage curves at constant plate currents for three of these tubes. Curves *A* and *B* are typical for gas content tubes and for amplifier tubes and are given for comparison. The slope of these curves is a measure of the amplification constant of the tube. The slope for the alkali vapor

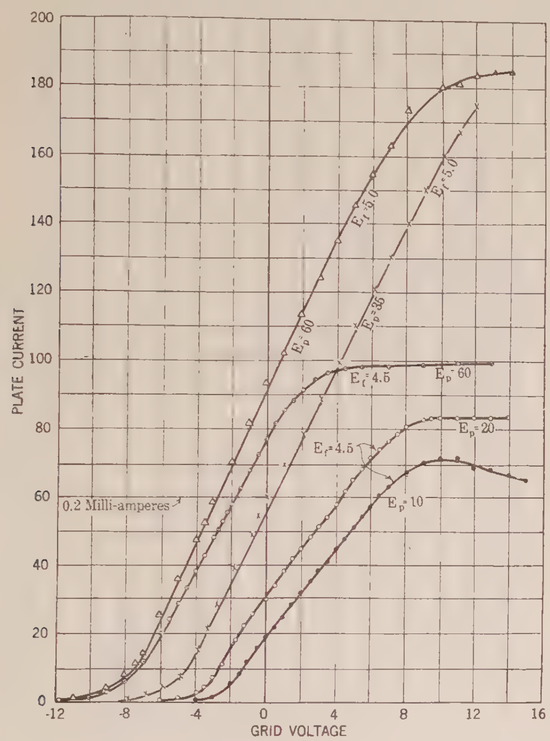

Fig. 7—K-Na Vapor Tube No. 22

tubes is steeper than that for the vacuum amplifier tubes, and the curves of the former are parallel straight lines.

The amplification constants of several tubes were measured for varying plate voltages by an audio-frequency a-c. method described on page 203 of Van der Bijl's "The Thermionic Tube." The results are shown in Fig. 12. It is not certain whether or not the high values obtained at low plate voltages were due to extra sensitiveness of the tubes, or to some discrepancy in the method when working at such low plate voltages. In the measurements the impressed 1000-cycle e. m. f. and the negative grid potential were varied, but no marked change in results occurred. It should be noted that the amplification constant falls off as the plate voltage is increased, and in Curve *A*, Fig. 13, it falls to zero at about 140 volts. However, increasing the filament current has the effect of keeping the curve from falling to zero, at least not until a considerably higher plate voltage is reached. In Curve *B* it is seen that the value of μ does not fall below 9.0 at 225 volts plate potential. In Fig. 14 are plotted values of mutual conductance for varying plate voltages, showing that the variation of this constant is much more gradual than it is for the case of gas content detectors.

IV. Detector and Amplifier Performance

One of the most important features of a detector tube is the degree of critical adjustment of plate voltage and

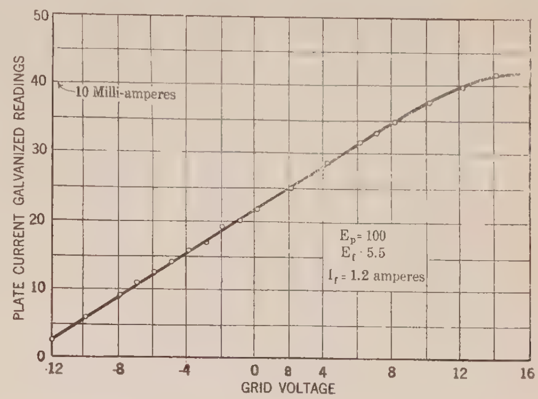

Fig. 8—K-Na Vapor Tube No. 22

filament current. It is known that low vacuum tubes, containing nitrogen, air, etc., (see Fig. 1) are quite critical. The alkali vapor tubes have been found to be much less critical in spite of the low plate voltages necessary for best efficiency, hence careful tests were made on several tubes used as detectors in laboratory receiving circuits, receiving modulated undamped waves

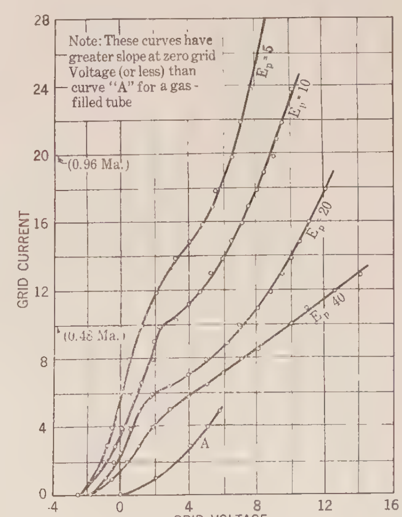

Fig. 9—Grid Current, Grid Voltage Characteristics, K-Na Vapor Tube No. 1

from a small loop transmitter. Measurements on the intensity of response in the telephones were made by matching the intensity of the received signal with another signal which could be attenuated in definite proportions from which per cent comparative audibilities could be calculated.[2] The results are shown in Fig. 15. Curves for low and high-vacuum tubes

are shown for comparison. Not only are the alkali vapor tubes much less critical than the conventional gas content tube, but the tests showed several of the former to be more than three times more sensitive than

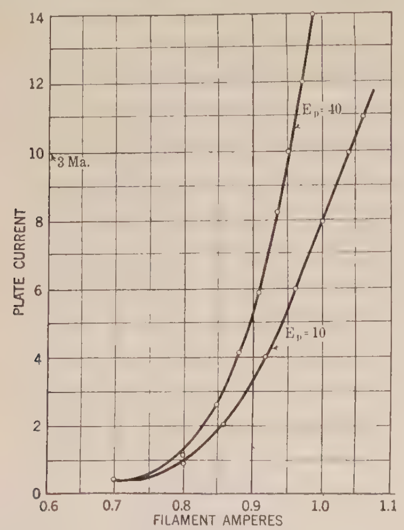

FIG. 10—K-NA VAPOR TUBE NO. 7
$E\,g = 0$

are the latter on weak signals, *i. e.*, three times as loud signal response. It is regretted that space does not permit a detailed discussion of the method of making the tests and the precautions[3] that are necessary.

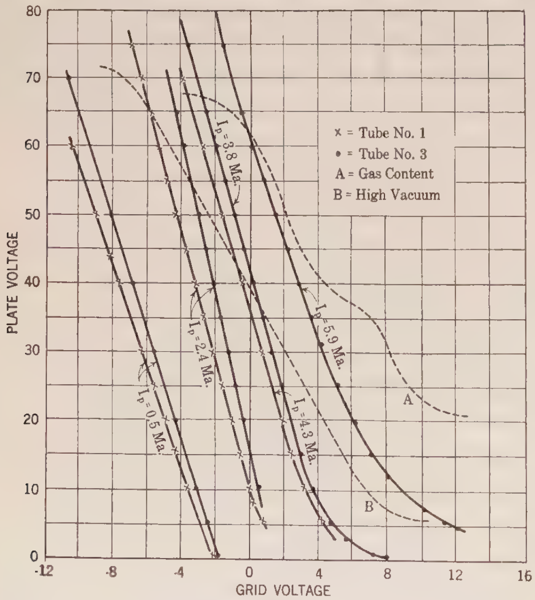

FIG. 11—K-NA VAPOR
x = TUBE NO. 1
• = TUBE NO. 3
A = GAS CONTENT
B = HIGH VACUUM

Another very interesting effect of filament temperature was here noted.

The value of μ, the amplification constant, and also the audibility, vary with the filament current in a manner similar to that of a high vacuum amplifier tube. These quantities increase from zero to full value rapidly as the filament current increases from 75 per cent to 90 per cent normal rated value, and they remain practically constant as the filament current increases to full value and on to 10 per cent above normal. Above this value the amplification constant falls off gradually.

If a tube contains considerable gas in addition to the alkali vapor the performance curve will be that of curve *A*, Fig. 15, having a second peak in the region of the ionizing potential of the residual gas. If now, the filament current is increased, say, from 0.97 ampere to 1.02 amperes, the second peak will entirely disappear, and the curve will be similar to one of those shown in the figure, say for tube No. 1. These results,

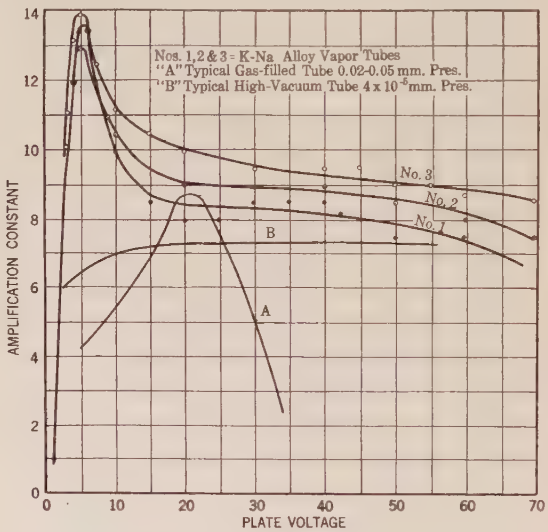

FIG. 12—VARIATION OF AMPLIFICATION CONSTANT WITH PLATE VOLTAGE

in addition to the mentioned effect of increased filament temperature on the amplification constant at high voltages, and the results showing effect on the characteristic curves, indicate that the heat of the filament makes the alkali vapor more effective in producing desirable characteristics that overcome the well known effects of the residual gas in tubes.

The quantitative results obtained indicate that potassium-sodium vapor tubes should be efficient and practical detectors. Actual use of these tubes has proved such to be the case to a surprising degree. The best plate voltage to use is about 8 or 10 volts. With this voltage users in this vicinity (Urbana-Champaign, Illinois) report excellent results. When using only the positive filament drop, with no additional "B" battery, the writers have often received broadcasting stations in Kansas City, Atlanta, Schenectady and Pittsburgh, using a variometer type of regenerative receiver with an antenna 12 ft. above the ground and 40 ft. long, and with *no* amplifier. The reception from the above

2. Van der Bijl's "The Thermionic Tube," pp. 337 and 347.
3. See paper by the authors, *Proc. I. R. E.*, Vol. 10, No. 6, pp. 460-3.

stations was fairly loud and very distinct. Again, using an antenna 40 ft. high, and with *no* external "B" battery, broadcasting stations in Los Angeles, Cal., were received fairly loud. The above stations could even be heard faintly with the plate circuit return connected to the negative filament lead, and with no "B" battery. With these conditions the tubes

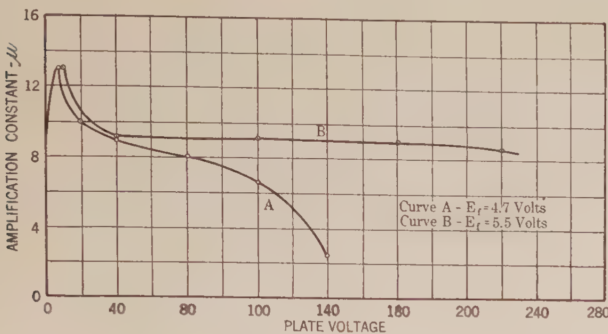

FIG. 13—K-NA VAPOR TUBE NO. 23

were also used as beat receivers of the autodyne type receiving the high-power stations on the coasts, when using the negative filament drop as plate potential. In addition to their high degree of sensitiveness the tubes have exhibited a remarkable degree of selectivity when functioning as detectors, especially in zero beat reception. They also give reception absolutely free from distortion which is not the case of many gas content tubes. In listening to piano music, for instance, every note in the runs was received perfectly clear and distinct.

When used in receiving circuits the tubes do not function efficiently until the filament has produced enough heat to render the alkali vapor active. This requires from 20 seconds to 1 minute. In most tubes the filament current can be maintained 10 to 20 per cent lower than for gas content tubes. Some of the alkali vapor tubes prepared in the laboratory have been used intermittently for 8 months, and no deterioration of the filaments has been noted. It is known that potassium and sodium can form alloys with tungsten, but it is very improbable that, owing to the filament temperatures, any alkali metal remains in contact with the filament. Another peculiar effect studied qualitatively is the ability of the tube to function most efficiently as a detector at a certain definite wave length. The wavelength of the transmitted signal was varied and the receiver tuned to receive it. The maximum audibility occurred at about 650 meters. Vacuum amplifier tubes did not show this effect when used in the same receiver.

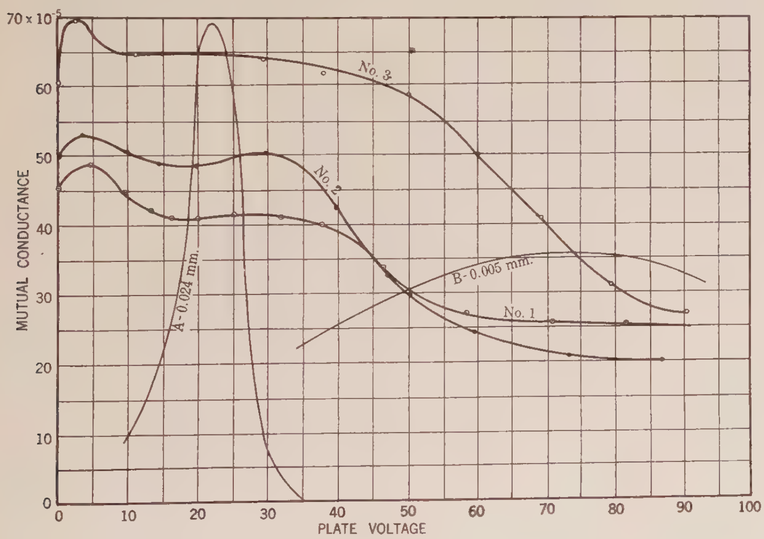

FIG. 14—NO. 1, 2 AND 3-K-NA VAPOR. A—TYPICAL GAS-FILLED TUBE; B—TYPICAL VACUUM AMPLIFIER

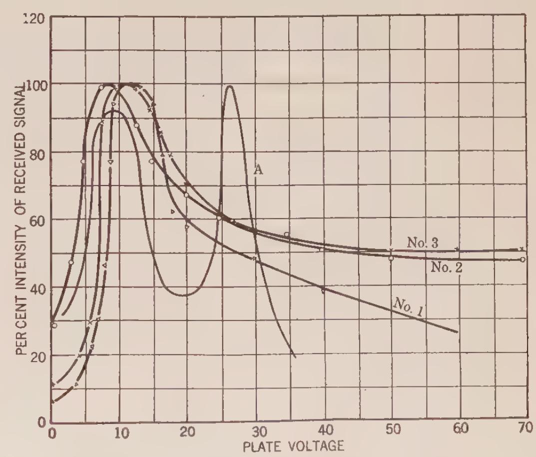

FIG. 15—DETECTOR PERFORMANCE, K-NA VAPOR TUBES

V. EFFECT OF VARIATION IN SPACING OF ELECTRODES

The foregoing data and discussion apply to the standard Radiotron U. V. 201 tubes, and also to a few tubes of different makes having nearly the same electrode spacings. To determine the effect of various spacings upon tubes primed with potassium-sodium alloy vapor was also undertaken. For tubes with slightly greater or slightly smaller spacings than those previously studied there was found no marked difference in the characteristics. When the spacings were increased to 6 mm. and 8 mm. from filament to grid, and to plate respectively, the amplification constant was found to pass through a maximum value for a plate voltage of 50 volts as the latter was varied. When the tube was used as a detector the audibility of the received signal was also maximum at this plate voltage, and passed through a maximum value for a filament current of about 50 per cent of the normal rated value as the latter was varied. Some of the results are shown in Fig. 16, and are typical for several tubes tested. Some of these tubes were extremely sensitive detectors under the above conditions, low filament current and high plate voltage and in the testing circuits gave approximately 10 times louder response than did those of normal spacing, but their action seemed erratic and

unsteady. The response at zero plate voltage was very weak. The characteristic curves of the tubes having large spacings proved to be similar in shape to those shown in this paper. The results of these tests indicate that in order to obtain the low plate voltage characteristics the spacings of the electrodes must be small.

VI. Oxide Coated Filament Tubes

The effect of potassium-sodium alloy in oxide coated filament tubes is very peculiar. Several of the "dry cell" types of vacuum tubes were filled with the alloy and proved to have extremely high plate resistance with normal filament current flowing. The measured *d-c.* plate resistance was upwards of a million ohms. The tubes were insensitive as detectors below filament currents that were 100 per cent above normal. This shows that for low temperatures the alkali vapor actually opposes the emissive power of the cathode, and it is only when the latter becomes so hot as to set the alkali vapor into very violent agitation that the plate current flows. Other effects such as contact potential, photo sensitivity, and ionizing action, probably combine in a complicated way to produce the results obtained. It should be mentioned that the Western Electric type VTI tubes primed with potassium-sodium alloy functioned fairly well as detectors at low plate voltages and normal filament current due to the considerable heat produced by the oxide coated filament in this type of tube. The application of heat externally improves their action. Characteristic curves obtained for such a tube are shown in Fig. 17. Due to the large increase in plate current when the voltage was raised from 10 to 20 it was necessary to lower the value of the shunt across the galvanometer that read plate currents, hence the two sets of coordinates. These curves are extremely steep and that they are shifted to the right of the zero grid voltage line as compared to the tungsten filament tubes is significant.

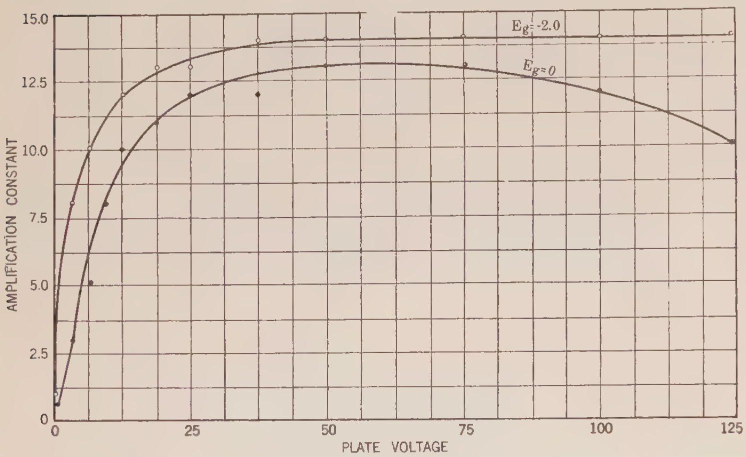

FIG. 16—K-NA ALLOY VAPOR TUBE WITH LARGE ELECTRODE SPACINGS, 50 PER CENT OF ARTED FILAMENT CURRENT

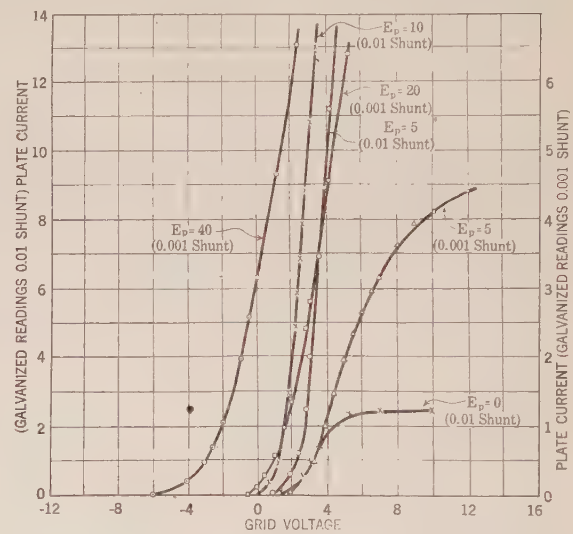

FIG. 17—WESTERN ELECTRIC V. T. I. TUBE, CONTAINING K-NA ALLOY VAPOR, NORMAL RATED FILAMENT CURRENT

VII. Summary

Three electrode tubes containing potassium-sodium alloy vapor, and probably other alkali metal vapors, were found to be very sensitive detectors in radio receiving circuits at low plate voltages. This sensitivity is due to the low ionizing potentials of these vapors, and probably also to other characteristics of such vapors, as photo-sensitivity, contact potential, etc. These tubes are much less critical than are gas content detectors. They are steady in their action, needing no frequent adjustments of filament current or plate voltages. The electrode spacings must be small to obtain the low plate voltage characteristics. Curves and measurements show excellent amplifier characteristics especially at higher filament temperatures. The effect of residual gas on the detector and amplifier characteristics is nullified by raising the filament temperature from 10 to 15 per cent. For sensitive detector operation the filament temperature necessary to make the alkali vapor active is a little lower than the rated value for that type of tube.

Credit should be given Dr. Jakob Kunz who recommended the alkali metal vapors in response to an inquiry as to what gases possessed the lowest ionizing potentials. The writers are also obliged to Mr. Orlando Whelan for valuable assistance.

The world's largest hydro-electric power unit was placed in operation at Niagara Falls, Tuesday, December 18, before a delegation of prominent electric power men and Government Officials in the new power plant of the Niagara Falls Power Company on the American side of the Niagara River.

The generating unit is a 65,000 kv-a., 107-rev. per min., 12,000-volt, 25-cycle vertical waterwheel driven generator, driven by a 70,000-h. p. hydraulic turbine, with a total weight of over 1750 tons.

Power Transmission

BY F. C. HANKER

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Introduction

THIS paper briefly reviews the development of power transmission, pointing out the power limitations of long distance, high capacity transmission systems. The paper serves as a general introduction to a group of papers, giving the results of analytical and experimental investigations of the power limits and stability of transmission systems. This group of papers which is to be presented at the A. I. E. E. Midwinter Convention includes, in addition to this paper by Mr. Hanker, papers by R. D. Evans and H. K. Sels; R. D. Evans and R. C. Bergvall; and C. L. Fortescue and C. F. Wagner.

The industrial supremacy of the United States can be traced directly to the general utilization of power in manufacture, transportation and agriculture. In their infancy, prime sources of power, both hydraulic and steam, were utilized directly, and consequently were relatively small in capacity and the use was restricted as to area. Today we can begin to appreciate the remarkable influence our electricity supply systems have had on the industrial expansion and can visualize to some degree the necessity of a national system that would remove any artificial barriers that arise in the path of full and free industrial development.

A similar condition existed in the development of the earlier power systems and the growth from the small isolated stations can be traced through several distinct stages. Initially, the area served was limited by the low voltage available for distribution and as a result only a small capacity station could be utilized. At that time the possibilities of voltage transformation were not recognized and, consequently, transmission and distribution were restricted to very nominal voltages. The advantage of the alternating-current system was soon appreciated, and as a result of the larger area it was possible to supply, the capacity of generating stations increased and the necessity for frequent stations of small capacity eliminated. The load on the early stations was almost entirely lighting and it was not until the advantages of the new power for industrial use became generally recognized that electricity supply systems became an important factor in the industrial expansion. As a result of the more general utilization of electric power through the development of higher voltages for transmission and distribution, small companies operating in adjacent districts were merged and the advantage of generation in larger units secured. In addition, there was the advantage accruing from the ability to supply diversified industries with less capital investment than by individual plants. From this condition, the second stage developed, and we had what may be termed group operation.

We are now at the beginning of the third stage, where the advantages of group operation have been fully realized and the desirability of the expansion of this plan is appreciated. Adjacent groups have interconnected, and with the full development, the economies of regional or national operation will be realized. A scheme of operation that will utilize the hydraulic resources of the country to the fullest extent will undoubtedly show the greatest economy. This cannot be accomplished by independent operation of different power units as it is impracticable to economically develop a number of projects due to the inability to utilize the power in a way that would justify the expense of development. With a well organized and practicable scheme of regional or national development it will be possible to work out a program that will gradually coordinate the available hydraulic resources with steam electric stations, utilizing various types of fuel to the fullest advantage.

The development of the art of generation and transmission soon attracted attention to hydroelectric possibilities located at points removed from the load centers that could utilize them to advantage. Studies of these propositions soon developed that there were definite limitations to the amount of power that could be transmitted over a single circuit without resorting to special conductor arrangements or intermediate regulating stations. Beyond these limitations the voltage conditions were found to be unstable and impossible of control. This situation led to careful analytical studies of fundamentals, so that today there is a fuller appreciation of the limitations of the system as a whole. Previous studies that have been published have dealt largely with individual units, as, for instance, a transmission line, without taking into full consideration the effect of the characteristics of the generating station, the transforming substation and the synchronous condenser equipment that would be required for voltage control. It was during the study of the transmission that was the basis of the general power system covered by the survey made of the districts contiguous to the northeast Atlantic sea-coast that improvements in the system layout were first given consideration by the engineers who have prepared the group of papers on this important problem.

The analytical studies made at that time indicated that the limitations to the amount of load that could be transmitted over a circuit could be increased materially by locating regulating stations at intermediate points along the line. These regulating stations would be

To be presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

essentially the same as terminal stations now in use on transmission systems where synchronous condenser equipment is utilized for voltage regulation. In a similar way the synchronous condensers would be utilized to compensate for the reactive component of the line. As these stations would not be prime sources of power, there was some discussion as to their operating stability. It was fully recognized that a similar system with generating stations located at corresponding points was entirely satisfactory, but with this type of station the prime movers would have drooping speed characteristics and furnish a stabilizing element to the frequency.

With the proposed method of operation utilizing intermediate regulating stations, it was recognized that a number of conditions existed that could not be analyzed completely, as there was no operating experience or test data that were applicable. There was a certain amount of information available from analyses of tests made a number of years ago, from which it was possible to predetermine with a fair degree of accuracy the characteristics of the tie lines necessary to maintain parallel operation of the generating stations. These data apparently indicated a limitation to the amount of power that could be transmitted that would render the scheme under consideration prohibitive. It was realized that the success of the suggested layout was dependent on the stability of the regulating stations, both as to frequency and voltage. For that reason it was felt that a comprehensive experimental investigation should parallel the analytical studies. This was considered essential, due to the numerous assumptions it was necessary to make of the operating characteristics.

The group of papers here presented discuss the subject in all its phases, and the results of the mathematical analyses have been fully checked by the tests made on the experimental lines discussed in the paper presented by Messrs. Evans and Bergvall.

In the papers on "Power Limitations of Transmission Systems" by Messrs. Evans and Sels, the analytical studies leading to an understanding of power limitations are fully outlined. A number of very interesting and valuable conclusions developed through the analytical studies have been fully confirmed by the test results that are given in the companion paper. Analytical studies of the problem, both general and specific, are given in the paper by Messrs. Fortescue and Wagner. All these studies cover important phases of the problem and, supported as they are by experimental data, will be extremely valuable to engineers investigating power projects where the amount of power to be transmitted exceeds present practise. The results have such an important bearing on the economic layout of transmission systems that the importance of the conclusions cannot be over-estimated.

Temperature and Pressure Correction Chart
for the Sphere Gap

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THE A. I. E. E. rules for the use of the sphere gap require a correction to be made to the indicated voltage for any variations of either temperature or barometric pressure from the standard values.[1] Where this correction has to be performed frequently the straight line chart here described has been found both to save time and insure accuracy.

The formulas for the correction factor are as follows:[2]

R = radius of spheres, cm.
t = temperature of air, deg. cent.
b = barometric pressure, cm.
δ = relative air density, 1 at 25 deg. cent., 76 cm. bar. pressure.
e_1 = spark-over voltage at standard temperature and pressure. $\delta = 1$. Given by tables.
e = spark-over voltage at temperature t, pressure b.
a = temperature and pressure correction factor.

Then

$$e_1 = a\,e \tag{1}$$

$$\delta = \frac{3.92\,b}{273 + t} \tag{2}$$

$$a = \sqrt{\delta}\left\{\frac{\sqrt{\delta R} + .54}{\sqrt{R} + .54}\right\} \tag{3}$$

A straight line chart giving the correction factor for a 25-cm. diameter sphere gap is shown in Fig. 1. The method of use is as follows. Lay a straight edge so as to connect the given temperature with the given pressure. Where it crosses the middle scale the reading gives the correction factor.

Example. Temperature, 19 deg. cent. Pressure 73.5 cm.
Correction factor, a = 0.988.

The method of constructing such a chart is best

1. Standards of the American Institute of Elect. Engrs. 1921. Sections 2366-2370.

2. F. W. Peek, Jr., Dielectric Phenomena, p. 94. Also F. W. Peek, Jr., The Sphere Gap as a Means of Measuring High Voltage. A. I. E. E. TRANSACTIONS 1914. Vol. XXXIII, Part 1, p. 923.

illustrated by describing in detail the construction of the one shown.

For a 25-cm. diameter sphere, R = 12.5 cm. and eq. (3) becomes,

$$a = 0.868\ \delta + 0.132 \sqrt{\delta} \tag{4}$$

Solving eq. (4) for $\sqrt{\delta}$

$$\sqrt{\delta} = \sqrt{1.152\ a + 0.00578} - 0.0760 \tag{5}$$

From eq. (2)

$$2 \log \sqrt{\delta} = \log 3.92b - \log (273 + t) \tag{6}$$

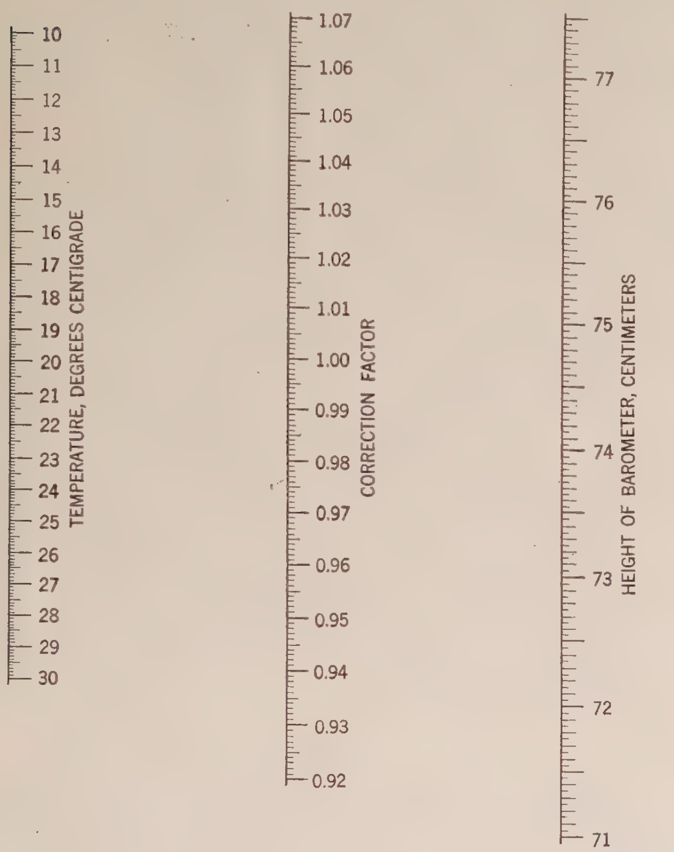

FIG. 1—TEMPERATURE AND PRESSURE CORRECTION FACTOR FOR 25-CM. DIAMETER SPHERE GAP

Directions: Lay a straight edge so as to connect the given pressure. Where it crosses the middle scale gives the correction factor.

In Fig. 2 is shown an elementary straight line chart from which it is evident that if the three axes are equally spaced, $2\,y = x + z$. This will express eq. (6) if,

$$y = \log \sqrt{\delta}$$
$$x = \log 3.92b$$
$$-z = -\log (273 + t)$$

It will also be seen that if instead of marking on the Y axis the value of $\sqrt{\delta}$ the corresponding value of a from eq. (5) is put down, then a can be read off directly. The following tables are then calculated to cover the desired range.

t	log 273 + t	b	log 3.92b	a	log $\sqrt{\delta}$
10	2.4518	71.0	2.4445	0.90	−0.0245
11	2.4533	71.5	2.4476	0.91	−0.0219
12	2.4548	72.0	2.4506	0.92	−0.0194
etc.		etc.		etc.	

The intervals given are close enough, as intermediate intervals can be obtained by subdividing these into equal parts. A suitable scale is now selected. In the original of Fig. 1 the scale was 0.0001 = 1/40 in. The temperature, t, pressure, b, and correction factor, a, axes are now drawn parallel and at equal intervals. The t and b scales are then drawn, in each case the position of one point on the scale being arbitrarily assumed and the other points laid off from this. It should be noted that pressure increases toward the top, temperature toward the bottom, that is, the scales are reversed

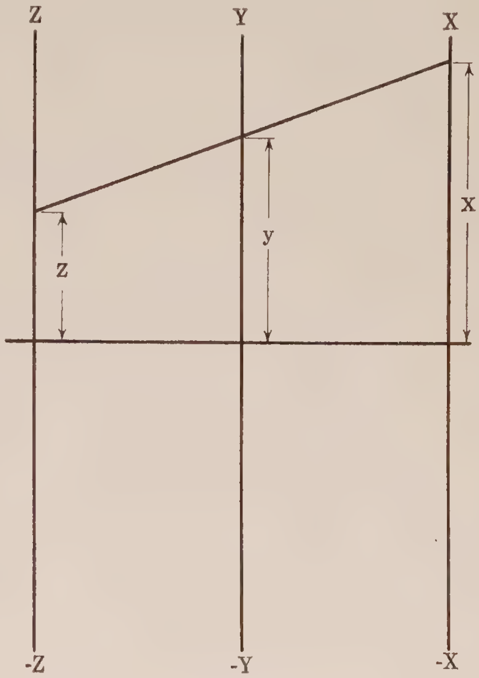

FIG. 2

with respect to each other. Next the position of a = 1 is found on the middle scale. This is most easily done by drawing a line from t = 25 to b = 76, these corresponding to a = 1. This point being located the rest of the scale can be readily drawn.

From this description and the equations given it will be easily seen how to construct charts for other diameters of spheres. If the barometer reads in inches, the chart may be adapted to this by changing the constants in eq. (2). A similar modification would permit the use of a Fahrenheit thermometer.

Reliable and comparable data are needed on the electrical resistivity at high temperatures of the refractory materials suitable for furnace linings. In the performance of experimental work by the Department of the Interior, at the Bureau of Mines Ceramic Experiment Station, Columbus, Ohio, methods and apparatus for making such measurements have been developed. Test pieces for determination of the electrical resistance were prepared from fire clay, kaolin, alundum, diaspore, thoria, silica, zirconia, magnesite, silicon carbide, sillimanite, zirkite and magnesium spinel.

High-Voltage Insulation

BY J. L. R. HAYDEN and CHARLES P. STEINMETZ

Member, A. I. E. E.

Fellow, A. I. E. E.
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I. General

THE most important chapters in electrical engineering are those dealing with efficiency, heating, magnetism and insulation.

In the field of insulation, our knowledge is most backward.

In regard to efficiency, with efficiencies of electrical apparatus of 90 up to over 99 per cent, no further radical progress appears feasible.

In magnetism, the losses in an alternating field have been reduced so far, that they have ceased to limit, by their heating effect, the size of apparatus, but are merely a factor in the efficiency. An increase of the saturation density would decrease the size of apparatus, but is excluded by its inherent chemical limitations.

Heating specifications are not made for other classes of apparatus, such as prime movers, etc., and if an important subject in electrical engineering, it is almost entirely because the insulation of the apparatus is destroyed by the higher temperatures. Thus the problem of the heating of electrical apparatus is essentially one aspect of the insulation problem.

In our high-voltage apparatus, cables, etc., we operate the insulation at voltage stresses which rarely exceed much the disruptive strength of air, though laboratory tests often show this insulation to have a disruptive strength of 10 to 20 times that of air.

All phenomena of nature are very complex. Therefore, in calculating a phenomenon or designing an apparatus, we must approximate by neglecting "secondary terms," and take care of these by an allowance, a margin or a factor of safety. Obviously, the more completely a phenomenon is known and understood, the closer it can be calculated, in other words, the less is the margin or safety factor required in order to allow for the unknown stresses, etc. The margin or safety factor, which experience shows as necessary, thus is an indication of the exactness of our knowledge of a phenomenon. For example when dealing with magnetic phenomena, with efficiency, with heating, etc., we have to allow a margin of a few per cent only. In testing the insulation of apparatus however, the A. I. E. E. standards specify a test voltage more than twice the delta voltage, though the normal stress is the Y voltage. That is, we require a safety factor of over 3.46, a margin above normal of over 246 per cent.

The insulation problem has become of increasing importance with the rapid advance of electrical engineering into higher voltages. Not many years ago 44 kv. was the highest transmission voltage for reliability of operation of overhead lines. Now we have reached 220 kv. Then 12 kv. was the highest satisfactory cable voltage; now we have reached 22 kv. and a few cables of 33 kv. and higher, but cables at 33 kv. are still semi-experimental. The comparison shows that the advance in pushing cable voltages up to higher values, has been slower than with overhead lines, and our knowledge of liquid and solid insulation, such as come into consideration in the cable wall and the machine insulation, is materially less advanced than that of air as dielectric. With regard to air, a good working theory has been established, by considering the dielectric strength of air as analogous to the mechanical strength of structural materials. The theory recognizes a definite dielectric strength of air, or a disruptive breakdown gradient, of 30 kv. per cm. at normal air density. Puncture occurs when this dielectric strength is exceeded, just as mechanical disruption occurs, when anywhere in a mechanical structure the stresses exceed the elastic limit of the material. This conception of a definite breakdown strength then was extended to liquid and solid dielectrics, but with these, it failed to give a satisfactory explanation of the mechanism of the breakdown, more particularly of the all-important feature of the time lag of disruption. And even with air, the theory of a constant breakdown gradient, as modified by the conception of the energy distance, is satisfactory only within a certain range.

Abridgement of paper presented at the Pacific Coast Convention of the A. I. E. E., Del Monte, Cal., October 4, 1923. Complete paper available without charge to members upon request.

II. Air as Dielectric

The present practically universally accepted theory of a dielectric strength of air at and near atmospheric pressure, as most completely developed by Mr. F. W. Peek, Jr., is:

Air has a definite and constant "dielectric strength," at which it ceases to be an insulator and becomes a conductor, that is, breaks down electrically.

The dielectric strength of air is proportional to the air density, and is 30. kv. per cm. at normal air density of 0 deg. cent. and 76 cm. barometer.

The dielectric breakdown (or puncture) of air does not occur as soon as the voltage gradient in the dielectric field exceeds the dielectric strength at any point, but the voltage gradient in the field must exceed the dielectric strength over a finite distance, the so-called "energy distance."

The energy distance depends on the convergency of the electric field at the place where the breakdown occurs, and is the less, the more convergent the field.

This standard theory of dielectric strength of air at and near atmospheric pressure is fairly satisfactory for gaps ranging between the energy distance and a larger value where corona begins.

For gap lengths less than the energy distance, the standard theory does not apply.

For gaps in which corona precedes the spark discharge, the law does not seem to satisfactorily agree with experience. Between spheres, corona appears only at gap lengths materially larger than those in which it should appear according to the theory.

The phenomena of vacuum tube conduction correspond to the phenomena occurring in very small gaps at atmospheric pressure, where the conventional theory does not apply, and the configuration of the field and the shape of the terminals become of lesser importance. Inversely, the voltage phenomena of the Geisler tube,

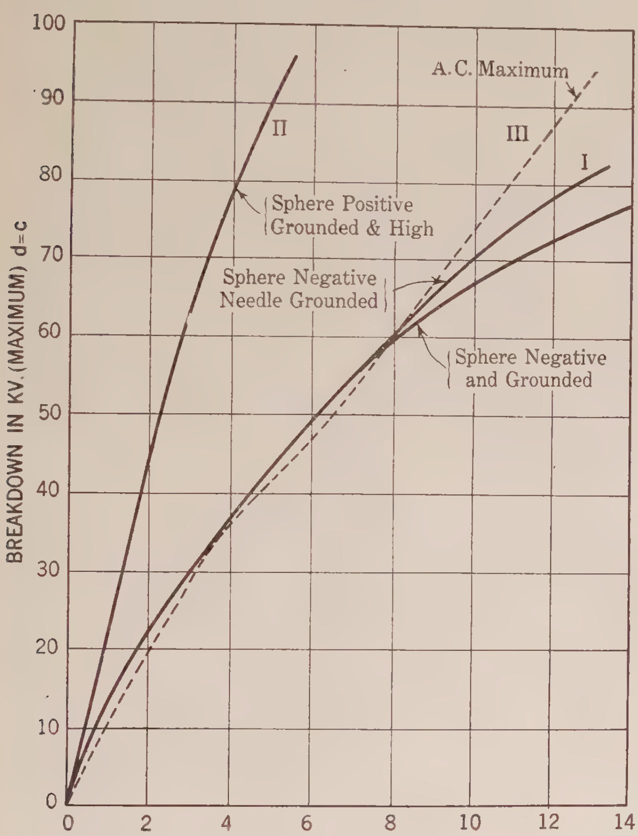

Fig. 1

may also appear in the dielectric strength of large gaps at atmospheric pressure, as terminal phenomena, though then secondary in magnitude to the gradient voltages of the dielectric field.

The conventional theory considers only the voltage gradient or intensity of the dielectric field as determining the dielectric strength, but not the direction, that is, assumes the same breakdown strength for either polarity of the impressed voltage. This resulted from the use of alternating voltages in determining the laws of the dielectric strength of air, due to high direct voltage of considerable power being unavailable until recent years. It is very far from correct, however, and in an unsymmetrical field, the disruptive strength with the voltage in one direction, may be more than twice that with the voltage in opposite direction. As illustration, Fig. 1 shows the striking distances between a needle and a 12.5 cm. sphere, for various gap lengths. Curve I gives the results with the needle positive, curve II with the needle negative, and curve III with alternating voltage. As seen, I and II differ greatly, II being more than twice the voltage of I. The alternating curve approximates I, as is to be expected. In the voltage range between I and II, such an unsymmetrical gap rectifies.

Investigation shows that it is the form and intensity of the dielectric field at and near the positive terminal which has the greatest effect on the disruptive voltage of the air gap, while the field at and near the negative terminal is of secondary importance. Thus if at constant gap length the positive terminal is gradually changed in steps from a sharp point to a flat plate, while the negative terminal remains unchanged in form, the disruptive voltage changes correspondingly over a wide range. A corresponding change in the physical form of the negative terminal however, with the positive terminal remaining unchanged in form, varies the disruptive voltage relatively little.

In Fig. 1, curve I approaches the striking distance curve between needles, as modified by the different distribution of voltage gradients due to the large negative terminal, and curve II similarly approaches the striking distance curve between 12.5 cm. spheres.

This suggests the explanation that the disruptive discharge is due to carriers of current produced by the field at the positive terminals, the positive ions possibly.

Tests made at atmospheric pressure on very small gaps—down to fractions of microns—show that with decreasing gap length the voltage does not indefinitely decrease, but reaches a finite minimum value, of about 320 volts, and becomes apparently constant at this value. This would be the minimum voltage required to disrupt an air gap, no matter how small. It means that with decreasing gap length, the voltage gradient of the air film rises to very high values, and such thin air films have an extremely high dielectric strength; gradients of 6.2 million volts per cm. have been reached.

Inversely, with increasing gap length, the voltage increases with the gap length, and proportional thereto, from an initial value of about 320 volts. The increase with increasing gap length, however, is not at the rate of the dielectric strength of air, 30 kv. per cm., as might be expected, but is at approximately twice this rate; about 60 kv. per cm., up to voltages of about 4500. Then the increase of voltage with increasing gap length decreases and approaches the normal value of the breakdown strength, 30 kv. per cm.

The voltage e required to break down an air gap of length l and uniform dielectric field intensity thus would consist of

(1) A constant voltage e_1 = 320 volts = 0.32 kv.
(2) A voltage gradient g_2 of about 60 kv. per cm.

over a short length $l_0 = 0.07$ cm., giving a constant voltage $e_2 = 60\, l_0$ kv.

(3) The voltage gradient of dielectric strength, $g_0 = 30$ kv. per cm., for the rest of the gap, $l - l_0$, or $g_3 = 30\,(l - l_0)$; thus giving a total voltage, approximately:

$$e = e_1 + e_2 + e_3$$
$$= 0.32 + 30\, l_0 + 30\, l$$
or, if $l < l_0$, simply
$$e = 0.32 + 60\, l$$

In a non-uniform field, the breakdown would occur from the positive terminal up to the distance, to which the breakdown gradient $g_0 = 30$ extends, and this space is filled with corona.

In Appendix I is given a suggestion of the mechanism of the dielectric breakdown of air by carriers issuing from the positive terminal.

III. Liquid Dielectrics

Oil and similar materials (as petrolatum in the high-potential cable impregnation) are the most important liquid insulating materials and are depended upon for the insulation of the highest voltage electrical

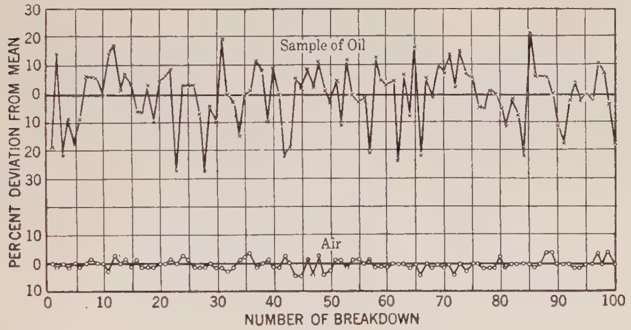

FIG. 2

apparatus, the transmission power transformer. The fairly satisfactory agreement of the behavior of air as insulating material, with the theory of a definite dielectric strength, modified by the conception of the "energy distance" led to the application of the same theory to liquid dielectrics. Here, however, the agreement with experience is not satisfactory; and tests show that oil does not have a practically available definite dielectric strength, but successive tests made with all precautions with the same oil in the same gap (using such a large quantity of oil as to exclude the effect of deterioration) differ from each other by values many times greater than the possible errors of observation. The upper curve on Fig. 2 shows the deviation from average of 100 successive tests of the disruptive voltages of an oil gap, and the lower curve shows the corresponding results with an air gap. Plotting the number of times each deviation from average occurs, in A, as function of the value of deviation, gives a probability curve.

The most satisfactory explanation of the mechanism of the breakdown of oil and other liquids seems to be that based on the assumption of lack of homogeneity, namely that the breakdown of an oil gap is the result of materials of different conductivity or specific capacity being sucked into the gap by the dielectric field, or being produced in the gap by it, and so causing a distortion of the field, with local high densities, at which disruption begins. This can be visually shown by dropping a minute quantity of water or other foreign material into an horizontal sphere gap in oil, at moderate voltage between the spheres, and observing the resultant motions and deformations. It is even somewhat questionable whether liquid dielectrics have a definite dielectric strength at all, or whether disruption does not always occur through gases produced from the dielectric by the electric stress. A discharge through oil seems always accompanied by the appearance of gas bubbles, and while the gas bubbles may not be the cause, but the result of the discharge, there are some differences in the shape of the striking distance curve of an oil gap from that of an air gap, which look as if the disruptive discharge in air is the result of the action of the dielectric field on the air, while the disruptive discharge in oil is the result of the action of the dielectric field on a material produced from the oil by the dielectric field, that is, the dielectric field produces dissociation or ionization of the oil, and the disruption occurs through the gases of ionization.

IV. Solid Dielectrics

The dielectric strength of solid dielectrics is often expressed by the disruptive voltage gradient in a uniform field, in kilovolts per cm., or per mil. Such an expression however, is meaningless, unless accompanied by a statement of the thickness of the dielectric, to which it applies, as the dielectric strength of solids varies with the thickness, sometimes by many hundred per cent. Besides this, the disruptive strength depends on the temperature, the duration and rate of the voltage application, the humidity, previous history of the sample, etc., and even with tests made under identically the same conditions, just as wide differences occur between successive tests of solid dielectrics, as shown by Fig. 2 to occur in liquids. The "disruptive strength of a solid dielectric" thus has only a limited meaning, and that, when the conditions are fully given.

Disruptive strength tests of solid dielectrics are usually made on sheets between metal plates as terminals, to produce a uniform dielectric field. This is open to the objection that at the edges of the terminals the field is not uniform. However, experience shows that puncture does not always occur at the edges of the terminal plates, but often inside, and by throwing out the tests in which the disruption takes place at the edge of the terminals, and averaging those in which the disruption occurs well inside of the terminals, fairly representative results are secured.

Two phenomena come into consideration in solid

dielectrics: The electric conductivity and the dielectric losses in an alternating field.

The dielectric has an appreciable though usually very low conductivity. That is, under an impressed voltage, a slight current is conducted through it, causing a loss of power and thereby a heating of the dielectric. The power consumed by ohmic conduction in the dielectric usually is extremely small, at least at atmospheric temperature. The conductivity usually increases very greatly with the temperature, often approximately exponentially, (for instance, increases ten-fold for every 25 deg. temperature rise, so that at high temperature the dielectric may become a good conductor). Often, the conductivity also increases with increasing voltage. In an alternating field, the resistance loss usually is very small compared with the other dielectric losses.

Under an alternating voltage, losses occur in the dielectric, more or less of the nature of a dielectric hysteresis. While probably mainly proportional to the frequency, some of these losses may increase faster than the frequency, some at a lesser rate, giving in the latter case a dielectric loss at zero frequency.

These dielectric losses may be represented by an energy current and an effective conductivity of dielectric hysteresis, and lead to a power factor of the dielectric. If the energy current of dielectric losses is proportional to the frequency and to the voltage, and the dielectric power loss therefore proportional to the frequency and the square of the voltage, then the power factor of the dielectric circuit is constant and independent of the frequency and the voltage. An increase of power factor with increasing voltage shows losses increasing faster than the square of the voltage, such as losses due to ionization of gas spaces inclosed in the dielectric; a decrease of power factor with increasing frequency shows losses increasing less than proportional to the frequency, or constant losses such as ohmic conduction losses.

The observation of the power factor thus is one means of judging the nature of the losses in the dielectric.

A dielectric of high disruptive strength in general has low conductivity and low dielectric losses, thus a low power factor in an alternating field; but the reverse is not necessarily the case, that is, a dielectric may have low conductivity or low power factor, and still be of poor disruptive strength.

It is doubtful whether a true dielectric strength of solid insulation exists, that is, a definite voltage gradient at which the dielectric is disrupted directly by the intensity of the dielectric field; or if it exists, it is so far beyond the disruptive strength observable, as to be of no practical consideration. That is, puncture of a solid dielectric probably in practise always occurs as the result of a more or less rapid progressive deterioration, far below the true dielectric strength, and the latter may be of moment only under direct lightning condition, for instance, in the puncture of a sheet of insulation by a powerful Leyden Jar discharge (giving the characteristic appearance of an internal explosion).

The mechanism of the breakdown of a dielectric under electric stress, may probably be any of a number of possibilities, thermal, mechanical, chemical, physical, etc.

Mechanism of Thermal Breakdown of the Dielectric as Third Class Conductor

Many, if not most of the dielectrics in reality are third class conductors, that is, have in some range of their voltampere characteristic such a high negative temperature coefficient of conductivity, that in temperature equilibrium the voltage decreases with increasing current.

Suppose a uniform sheet of solid dielectric is exposed to a constant direct voltage between two conducting terminals. Due to the slight conductivity of the dielectric, a current then flows through it at a uniform, though very low current density. This consumes electric energy, converting it into heat, and gives a slight temperature rise of the dielectric. Now, no material can be absolutely uniform and homogeneous, and thus in this sheet of dielectric there will be some spots of a slightly higher conductivity. However slight the difference, at such a spot the current density must be slightly greater, thus the energy consumption and the heat production slightly greater, giving locally a slightly higher temperature rise. However little this may be, if the conductivity of the dielectric increases very rapidly with increasing temperature, it will lead to a slightly higher current density, a correspondingly higher energy consumption and heat production and thus temperature rise, and so on. Two possibilities then exist, either the heat which can be conducted away from such a "hot spot" due to its temperature rise, is more than the heat produced by the increased conductivity due to the temperature rise. Then the temperature of the hot spot finally limits itself, and stable thermal conditions pertain. Or the heat which can be conducted away from the hot spot into the dielectric, by the temperature rise, is less than the heat produced in the dielectric by the increased conductivity due to the temperature rise. Then the conditions are unstable, that is, the temperature continuous to rise and the conductivity to increase indefinitely, until the energy concentration at the hot spot becomes destructive, and the dielectric is destroyed by "puncture."

The successive steps of this phenomenon have been observed by limiting the current density by suitable terminals and can be calculated from tests made on the conductivity of the dielectric at various temperatures and voltages.

As the energy consumption by the conduction current varies with the square of the voltage, there is thus a definite voltage—for a given set of conditions—at

which instability is reached and puncture results, and this voltage is the "breakdown voltage," its voltage gradient the "dielectric strength" of the material under the conditions of test. This voltage depends upon the initial temperature, and considerably decreases with increasing temperature; at higher temperature, a lesser temperature rise is necessary to reach unstable conditions, and at the higher initial temperature the phenomenon starts with a higher conductivity, that is, greater power consumption and heat production. The heat conductivity of the dielectric and of the terminals and other surrounding objects, and their ability to quickly absorbing heat, that is, their specific heat, are essential factors in determining the value of the puncture voltage. An essential factor also is the relation between temperature and conductivity of the dielectric, etc., so that the "dielectric strength" thereby determined, is very far from a constant for the material.

Suppose the "hot spot" is filamentary in shape. That is, the diameter of the spot of slightly higher conductivity (or temperature) at which the breakdown starts, is small compared with its length in the direction of the lines of force, so that heat conduction from it is essentially into the dielectric. Then a change of thickness of the dielectric will not affect the heat conduction, and in this case it follows that the disruptive voltage is proportional to the thickness of the dielectric, its dielectric strength independent of the thickness.

Suppose however the "hot spot" is plate-shaped, that is, its dimension parallel to the lines of force (from terminal to terminal) is small compared with its diameter parallel to the terminals, so that the heat conducted from it flows into the terminals. Then an increase of thickness of the dielectric gives an increase of heat to be conducted through a longer distance through the same area, thus instability is reached at a lower voltage gradient. In this case it is found that the puncture voltage is proportional to the square root of the thickness of the dielectric, and the dielectric strength inversely proportional to the square root of the thickness.

In general then, in dielectric breakdown by temperature instability, depending on the path of the heat conduction, the puncture voltage varies between the first and the 0.5th power of the thickness of the dielectric, and the dielectric strength or breakdown gradient varies between independence of the thickness, and the—0.5th power of the thickness of the dielectric.

This phenomenon of dielectric breakdown by thermal instability is the result of the increase of energy loss in the dielectric, with increasing temperature, and occurs wherever the losses greatly increase with the temperature. While its mechanism has been illustrated above on ohmic conduction in a direct-voltage field, the same phenomenon occurs in the same manner in an alternating field, and as the result of the specific losses of the nature of a dielectric hysteresis, as far as these losses increase with the temperature. The increase—and usually very rapid increase—of the power factor with the increase of temperature of most dielectrics shows that the losses in the dielectric in an alternating field, increase with the temperature, and thermal instability leading to puncture at "hot spots" thus results.

Mechanism of Disruption Due to Mechanical Instability

Suppose a dielectric encloses a particle of a higher conductivity or higher specific capacity. An electric field then exerts a mechanical force on this particle, which tends to elongate it in the direction of the electric field, and to compress it at right angles thereto, that is, tend to form it into a filament short-circuiting the dielectric field. With liquid dielectrics, this can be observed visually by dropping a little water into a horizontal sphere gap in a transparent oil. Each droplet, as it is sucked into the field between the spheres, lengthens into a filamentary conductor which bridges between the terminals, and then is destroyed with a flash by the heat of the current conducted by it. A similar phenomenon occurs with moisture in a solid dielectric, except that the puncture usually is permanent; occluded moisture moving under electrostatic forces through the pores of the solid dielectric, may form a conducting bridge between the terminals and by the heat of the current in the moisture filament start destruction of the dielectric. Or the moisture-thread may partially bridge between terminals and locally short-circuit the field, which will cause excessive dielectric stresses in the part of the gap in series with the moisture filament. In these over strained portions of the field, destruction starts by thermal or chemical instability, etc.

In impregnated insulation, where the impregnating material is liquid or viscous, motions of the impregnating material through the impregnated material may result from the mechanical forces caused by differences in specific capacity or conductivity of the materials, leading to a redistribution of the impregnating material. Conductivity and specific capacity here act in the same direction, in general. The differences in specificcapacity of different dielectrics are however relatively small; rarely more than 1 in 6 in materials which are suitable for apparatus insulation; while the same constituent materials may differ in conductivity over an enormous range. The final effect of conductivity as compared to specific capacity is likely therefore, to be much greater. On the one hand, the mechanical forces due to differences in specific capacity appear instantaneously, and thus are present also in alternating fields. On the other hand the differences due to difference in conductivity appear gradual, being accompanied by the formation of local internal electrostatic charges, and may require seconds or even minutes for their completion. These local changes would not be present or

only partly present in alternating fields, and the mechanical actions of alternating fields thus differ from those of continuous fields. This can conveniently be observed visually on sphere gaps in oil.

Mechanism of Disruption by Chemical Deterioration

Suppose the dielectric contains a particle of higher specific capacity or higher conductivity. Let us assume, at first, this particle to be spherical in shape, and of relatively infinite specific capacity or conductivity, that is, short-circuiting the field (for instance, an oil of 10 megohms resistivity would fulfil this condition in a dielectric of 1000 megohms resistivity). Then the density of the lines of dielectric force inside of the spherical particle is three times that in the surrounding dielectric, and—at least temporarily, until a redistribution of internal charges has occurred—the density of the lines of dielectric force and thus the voltage gradient in the dielectric outside the poles of the spherical particle would be three times normal. It would be less than three times normal, if the specific capacity or conductivity of the spherical particle differs less than given above from the surrounding dielectric. But it would be greater if the particle is not a sphere, but more irregular in shape, and would assume much higher values at the edges and at points of the particle. Thus in the dielectric adjacent to edges or points of an enclosed particle of higher specific capacity or conductivity, very high-voltage gradients occur, and may be far beyond the dielectric strength of the material, and lead to local breakdown of the material by what may be called "electrostatic cutting edges." With organic insulation, the effect usually would be carbonization by high local temperatures, a chemical change which in general increases the conductivity. The mechanical electrostatic forces brought about hereby are in the direction of the field, so that the shape of the product of chemical deterioration tends toward the form of a conducting needle, with excessive voltage gradients in front of it, gradually piercing the dielectric until final puncture occurs between the terminals. Thus in a laminated insulation consisting of very many layers, a foreign particle in one of the layers though originally forming only an insignificant part of the total thickness of the dielectric, may gradually but cumulatively, in the course of time, pierce and destroy the insulation by its electrostatic cutting edges, the average voltage gradients within the dielectric, being still very low compared with the tested "dielectric strength" of the material. The destruction will be the faster, the higher the local voltage gradient. This seems to be the main reason why such excessive margins are required in high-voltage insulation, to give reasonable length of life.

Ionization

The specific capacity of the common solid dielectrics is from 2 to 8 times that of air. Thus if air pockets are contained in the dielectric, the electric stress in the air is much higher than in the solid, and as the break down gradient of air is low, it breaks down with the formation of "corona," giving heat and chemical action, and such ionization due to enclosed air probably is a frequent cause of disruption. It is guarded against by excluding the air by impregnation with a material of higher dielectric strength and higher specific capacity, such as oil. It means however, that the process of impregnation to be effective must be perfect.

It is interesting to note that some of the mechanisms of breakdown, as thermal instability and mechanical forces, are reversible, that is, at the withdrawal of the voltage, the original condition may gradually return, leaving the dielectric undamaged, while the chemical deterioration by the electrostatic cutting edges or by ionization is irreversible, that is, what damage has been done is permanent and remains at the withdrawal of the voltage, and at the next application of voltage, the deterioration progresses further.

In non-homogeneous dielectrics, such as laminated insulation, due to the differences in the ratios of the respective specific capacities and the specific conductivities of the component dielectrics, gradual changes may occur in the distribution of the voltage gradients through the dielectric, with the formation of internal charges, which continue for some time, thus resulting in a corresponding change of the dielectric stresses.

V. Time Lag of Insulation

The two important properties of insulation are its dielectric strength and its time lag. The former means that there is a limit in the voltage gradient up to which an insulation can hold back the voltage, and when this voltage gradient, the "dielectric strength" or "disruptive strength" of the insulation, is reached, disruption occurs and the insulation ceases to insulate, becomes a conductor.

Experience shows the following condition: At least with very many insulations, the voltage at which disruption or breakdown occurs, depends on the time or duration of voltage application. The lower the voltage, the longer the time it has to be applied. There is a minimum voltage, which continuously applied, still just disrupts the insulation, and inversely, the higher the voltage, the shorter is the time during which it has to be applied.

This time, during which a given voltage has to be applied to cause disruption, is called the "time lag" of this voltage. The ratio of this particular voltage of brief application to the voltage which permanently applied breaks down the insulation, is called the "impulse ratio" of the time of voltage application.

Time lag bears to dielectric strength, in electrical engineering, a relation similar to the one between elasticity and mechanical strength in mechanical engineering; if it were not for elasticity, there would be no mechanical engineering. A pebble dropped on

an armor plate would shatter it,—since theoretically, at the point of impact, without elasticity infinite mechanical forces would be produced.

So without the phenomenon of time lag, there would be no electrical engineering, as there would be no possibility of insulation, since every insulation, even a low-voltage lighting circuit, is theoretically constantly exposed to transients of infinite voltage (though negligible energy), that is, far beyond its possible dielectric strength, by the inductive and capacity effects of any change of circuit conditions, and thus saved only by the time lag of its insulation.

Just as the relations between mechanical strength and elasticity give the wide variety of structural materials, on which the mechanical engineer depends, and which we denote by brittle, tough, ductile, elastic, rigid, flexible, yielding, etc., etc., so the relation of time lag to dielectric strength gives us insulating materials of widely different properties and correspondingly widely different uses—but our knowledge in this field is unfortunately still very limited.

To illustrate the importance of the time lag: Experience as well as calculation shows that in 2300-volt primary distribution circuits during thunder storms, potentials of short duration of the magnitude of hundred thousand volts are not infrequently produced by the setting free, by the lightning flash, of the bound charge of the atmospheric electrostatic field. The lighting transformers distributed over these circuits are not, and economically cannot be insulated to stand this voltage continuously. Hence, they must depend on the time lag of their oil insulation to stand the lightning voltage until it is dissipated or discharged by the lightning arrester. Inversely, the time lag of the lightning arrester must be so short, and its discharge rate so high, as to discharge the lightning voltage in a time less than the time lag of the transformer, bringing the voltage down to values safe for the transformer.

From the pnenomenon of time lag it results that the rate of voltage application has a discriminating effect. Suppose two insulations are used in parallel, the one of lower dielectric strength but higher time lag than the other. (As for instance, the oil insulation of a transformer and the surface air insulation of its entrance bushings). At very rapid voltage application, the voltage may rise beyond the dielectric strength of the stronger insulation of shorter time lag, in less than the time lag of the weaker insulation, and the former thus punctures, while with a slower voltage application the weaker insulation of greater time lag would puncture. Thus under lightning conditions, the transformer bushings may flash over, short-circuit and blow the fuses without any damage to the transformer, while under high potential test the oil insulation may puncture far below the voltage at which the bushings flash over.

To illustrate the importance of this discriminating effect of rate of voltage rise: The insulation of high-voltage transmission lines depends on sectional or string insulators. With these, it is very desirable that in case of a failure the insulator disks should flash over rather than puncture. The transmission insulators thus are designed for a puncture voltage much higher than the flashover voltage, and 60 cycles tests as well as high-frequency tests show such insulator strings to flash over and not to puncture. Nevertheless lightning punctures them not infrequently. The time lag of flashover is greater than that of puncture, due to the relatively high capacity of the insulator string. Therefore, under lightning conditions, that is, very rapid application of voltage of considerable energy, the voltage reaches puncture values in less than the time lag of flash over, while in low-frequency tests flashover limits the voltage, and in high-frequency tests the rate of voltage application is reduced, that is, the wave front flattened by the capacity of the insulator string, unless there is very great power back of the voltage, so as to maintain it against the short-circuiting effect of the capacity of the testing appliance (so-called "lightning generator").

Time lag of Solid and Liquid Insulation

When the mechanism of the dielectric breakdown of the insulation consists of a cumulative thermal, mechanical or chemical effect, as discussed above, it inevitably involves a time lag, and usually a considerable one.

This time lag may be as short as a fraction of a second, such as occurs in the electrostatic field of an oil gap sucking in a moisture droplet, stretching it into a filamentary conductor, bridging between the electrodes and flashing over. In the formation of hot spots in solid insulation, it may take minutes and hours, until the process leads to the final disruption, and may extend to days and years in the chemical action of ionization, etc., so that here the time lag of the insulation breakdown gradually merges into the aging or deterioration of the insulation.

For instance, under overload a cable may get overheated and some hot spots form in the insulation and finally, after some hours, lead to a puncture. If however the load is taken off before the final breakdown, the cable cools and the hot spots disappear and leave the insulation undamaged, and we say that the cable has been saved by the time lag of insulation and no harm done by the temporary overload, because in this case of approaching thermal breakdown the process is reversible.

If however, under high-voltage test, ionization occurs in the cable and by chemical action begins to destroy the insulation, we also may say that the cable is saved by the time lag of chemical breakdown, if the overvoltage is taken off before failure has occurred. However, as this process is not reversible, some damage has been done, and at the next overvoltage further damage is done and adds itself, until final disruption occurs.

In some respect, we may thus consider the gradual and slow aging and deterioration of the insulation during the years of use, which limits its final life, as a progressive breakdown, and the entire life of the insulation as the time lag of breakdown; however, this rather extends the meaning of the term.

Electrical Time Lag

Air apparently has no time lag, at least, no appreciable time lag, and the dielectric breakdown of the air gap between spheres at a distance greater than the energy distance and less than the corona distance, with a negligible impedance between spheres and the source of voltage supply, is as nearly instantaneous as can be measured. Time lags (or impulse ratios) with air gaps therefore are due either to the configuration of the gap, or due to the conditions of the supply circuit.

A sphere gap with a considerable resistance in series has an appreciable time lag, the greater, the higher the resistance, due to the time required to charge the capacity of the spheres over the resistance.

By shunting an instantaneous sphere gap by a small capacity C, with a non-inductive resistance r in series, any desired time lag can be produced by the proper choice of C and r, and such a combination thus forms an adjustable time gap, convenient for the testing of time lags.

INDUCTION IN A CIRCUIT HAVING NO RESISTANCE

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The now classic and interesting experiment of Onnes is quite instructive. By reducing the resistance of a solid copper ring to very nearly zero (by lowering its temperature to nearly absolute zero) he found that when a current is started in this ring it continues to flow for a long while, because the resistance to its flow is nearly zero.

This experiment has raised the question, of theoretical rather than practical interest, what would happen if the ring had absolutely no resistance. One noted physicist said to the writer that according to Maxwell it would be theoretically absolutely impossible to induce any current at all in it. Another noted physicist said to the writer that the slightest induced voltage would necessarily induce an infinitely large current. A difference between zero and infinity is about as large as it could be, hence there is something wrong somewhere with our "knowledge".

It is another illustration of the danger of plunging into that abyss, infinity, (and sometimes its somewhat less dangerous partner, zero), which plunge mathematicians seem to take so unhesitatingly. A safe way is to assume the resistance to be nearly but not quite zero. That lets out Maxwell. Would the current then be enormous with the slightest induction.

If the induction is then produced by moving one pole of a magnet through it, an enormous current would mean an enormous field which it seems would be so great that it would be practically impossible to move the magnet at all. If the induction is produced by opening the circuit of a neighboring current-carrying coil, the enormous field produced by an enormous current in the ring, would seem to mean that the energy of the reaction on the inducing coil would be greater than the energy which had been stored in it, which would be impossible.

The writer ventures to suggest the following. The energy stored in the ring by induction resides in the magnetic field encircling it when current flows. It may be pictured as a strain or stress in the surrounding ether. This energy could not possibly be any greater than that used up in producing it. Hence in the opinion of the writer, the current induced would be limited to that which would produce a magnetic field whose energy is equal to that set free by the inducing element, be it by mechanically moving a pole, or by opening a nearby current carrying circuit. As the energy of such a field increases with the square of the current, hence much more rapidity, a limit to the induced current ought soon to be reached and it would seem that the current would therefore be quite limited and not enormous. If, for instance, the ampere-turns in the inducing coil (assumed to be very close and of equal size) were say 100, it would seem that the induced current in the ring would be only just about 100 amperes, and no spark should be produced at the opening switch. The elastic flux cannot collapse (thereby inducing a current in the ring) as that would increase the current, which of course would be impossible.

The Onnes experiment is of practical interest in that it affords a rare and unique opportunity to study (apparently for the first time) the stored energy of an electromagnetic system by itself, that is, without connection to any source of new energy. Heretofore such a system was always studied (as in the Kelvin law) under "constant current" conditions, which means a joint action of two things, the stored energy and new energy and this, like one equation with two unknowns, is incomplete information. By using the Onnes experiment as a basis the writer has shown by deduction (A.I.E.E. Journal, Feb. 1923, p. 153) that when an electromagnetic system by itself does any work the flux *diminishes*; it does not always increase as is generally erroneously believed and taught.

A new edition of the Bureau of Standards Circular on Electric Service Standards has just been issued by the Department of Commerce. The material contained in the old edition has been revised when necessary and brought up to date. The first edition has been the basis for many of the rules in force in many States.

CORRESPONDENCE

PROPAGATION OF DISCONTINUITIES OF THE FIRST DERIVATIVE OF VOLTAGE AND CURRENT ALONG AN ELECTRIC LINE

To the Editor:

It has been proved by the writer[1] that a discontinuity of the magnitude of voltage or current is always propagated along any electric line at the velocity of light in the surrounding medium ($v = 1 : \sqrt{LC}$), whether or not there is resistance and leakance present. It has been asked by Dr. Bush if it is not true that this discontinuity of voltage or current may be either a discontinuity of magnitude or simply of derivative. Thus, if a sinusoidal voltage is applied to a long transmission line at the zero of voltage, the discontinuity which travels has no steep wave front; what is propagated in this case is a discontinuity of derivative only of voltage and current. There is no doubt about this discontinuity being also propagated along any line at the velocity of light, whether or not there is resistance and leakance. The following may be a proof for it.

The voltage V and the current I along a line are connected together by the well-known equations, where R, L, G, C represent the four constants of the line as usual:

$$L \frac{\partial I}{\partial t} + R I = - \frac{\partial V}{\partial x} \qquad \textbf{(a)}$$

$$C \frac{\partial V}{\partial t} + G V = - \frac{\partial I}{\partial x} \qquad \textbf{(b)}$$

By eliminating V or I between these equations, the same equation of propagation is obtained for V and I. (equation **1** in paper.)

Let us consider a point M (x, t) along the line, at which V and I are continuous functions of x and t, but where $\partial V / \partial x$ is a discontinuous function of x. Let this discontinuity be propagated at an unknown velocity v. We will show that v must necessarily be equal to $1 : \sqrt{LC}$. After the time Δt has elapsed, the discontinuity will have traveled from M (x, t) to M' $(x + v \Delta t, \; t + \Delta t)$. Let us express the fact that the voltage V, which is continuous at M, is still continuous at M'. Calling V_1 and V_2 the values of the voltage left and right of M and infinitely near this point, we have

at M $\qquad V_1 = V_2$

$$\text{at } M' \quad V_1 + \frac{\partial V_1}{\partial x} \cdot v \Delta t + \frac{\partial V_1}{\partial t} \Delta t$$

$$= V_2 + \frac{\partial V_2}{\partial x} \cdot v \Delta t + \frac{\partial V_2}{\partial t} \Delta t$$

hence, $\qquad v \overline{V}_x + \overline{V}_t = 0 \qquad$ **(c)**

denoting by $\overline{V}_x$ the discontinuity of the space-derivative of the voltage at M (x, t), *i. e.*, $\partial V_2 / \partial x - \partial V_1 / \partial x$, and by $\overline{V}_t$ the discontinuity of the time-derivative of the voltage at the same point M (x, t), *i. e.*, $\partial V_2 / \partial t - \partial V_1 / \partial t$. It is seen from (*c*) that when a discontinuity $\overline{V}_x$ exists at a point M (x, t), it is necessarily accompanied by another discontinuity, $\overline{V}_t$, at the same point M (x, t).

Let us now assume that V is continuous at M. We have as above $V_1 = V_2$. By means of (*b*), this becomes

$$C \frac{\partial V_1}{\partial t} + \frac{\partial I_1}{\partial x} = C \frac{\partial V_2}{\partial t} + \frac{\partial I_2}{\partial x}$$

where I_1 and I_2 denote the values of I left and right of M and infinitely near this point. Using for the derivatives of I notations similar to those used for V, we get from the preceding equation

$$C \overline{V}_t + \overline{I}_x = 0 \qquad \textbf{(d)}$$

which shows that a discontinuity of V/t at the point M (x, t) entails a discontinuity of I/x at the same point M (x, t).

Similarly, assuming that I is continuous at M and using equation (*a*), we obtain

$$L \overline{I}_t + \overline{V}_x = 0 \qquad \textbf{(e)}$$

which shows that a discontinuity of $\partial V / \partial x$ at the point M (x, t) entails a discontinuity of $\partial I / \partial t$ at the same point M (x, t).

Expressing finally, as we did for the voltage, that the current I, which is continuous at M (x, t), is still continuous at M' $(x + v \Delta t, \; t + \Delta t)$, we get similarly

$$v \overline{I}_x + \overline{I}_t = 0 \qquad \textbf{(f)}$$

which connects the two discontinuities of I at the same point.

There are thus four homogeneous linear equations (*c*, *d*, *e*, *f*) connecting the four discontinuities $\overline{V}_x$, $\overline{V}_t$, $\overline{I}_x$, $\overline{I}_t$. In order that the system of equations may be compatible, the following relation must be verified

$$\begin{vmatrix} v & 1 & o & o \\ o & C & 1 & o \\ 1 & o & o & L \\ o & o & v & 1 \end{vmatrix} = 0$$

or, developing the determinant,

$$v^2 L C - 1 = 0.$$

This shows that the velocity of propagation v of a discontinuity of the derivative $\partial V / \partial x$ is necessarily equal to $1 : \sqrt{LC}$, which is the velocity of light in the surrounding medium. Moreover the four above equations prove that, V and I being continuous functions of x and t, the mere existence of a discontinuity of any one of the derivatives of V and I at a point M (x, t) entails the existence of discontinuities of the three other derivatives at the same point M (x, t). They are all propagated together at the same velocity v.

The discontinuity of voltage which is produced when a sinusoidal voltage is impressed on a long transmission line at the zero of voltage is a particular case of the preceding.

CHARLES MANNEBACK

Brussels, Belgium, November 18, 1922.

1. Manneback, Charles; *Radiation from Transmission Lines*, JOURNAL of the A. I. E. E., February, 1923. p. 95.

Power Limitations of Transmission Systems*

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Review of the Subject—*Several independent studies have been made recently to determine the economies of a large, uniform power system. The two studies of more general interest were those conducted by the Department of the Interior, under the direction of W. S. Murray, for the Superpower Zone, and by F. G. Baum for the United States. Both of these investigations are available in published form.*

During the progress of the Superpower Survey, one of the longest transmission lines proposed was that extending 350 miles from the Niagara Falls Development to New York City. Under emergency conditions on this line, the power limit for the maximum amount of power was approached by two twin-circuit tower lines with three circuits carrying the emergency load. The maximum power limit would have been exceeded if two single-circuit tower lines had been employed, even though the transmission voltages and the total copper cross-section were the same as with the two twin-circuit tower lines. Similarly, several long, high-voltage lines will be required in a nation-wide system, especially through the middle western region as shown by Mr. Baum's report. The tendency to extensive transmission systems has emphasized the necessity of considering the factors which will limit the amount of power that can be transmitted any distance with the highest practical transmission voltage. On account of the transmission line characteristics, the power limits will be greater when the system is regulated by synchronous apparatus than when those such apparatus is used so that two power limits will be considered in this paper; first, for an unregulated system; and second, for a regulated system. However, while we are primarily interested in high-voltage systems in this paper, it should be kept in mind that these same methods of calculation may be applied to lower voltages in determining the power limitations of station tie lines.

It is commonly accepted that different types of networks have certain power limitations. For example, a very simple case quite generally known is that of a simple resistance circuit in which the power delivered is a maximum when the resistance of the load is equal to that of the line. Another familiar case is that of the electric arc furnace where the maximum power occurs when the resistance of the furnace arc is equal to the reactance of the electric furnace leads. The general phenomenon of maximum power limit in circuits of fixed reactance and variable resistance or load has been recognized and its theory worked out for numerous cases, such as short transmission lines, rotating machines, and transformers.

A power transmission system may be regarded as a special type of network. Ordinarily it consists of long, high-tension transmission lines and apparatus connecting generating stations with distant load centers which may be either at the terminus or at intermediate points on the high-tension lines. In large systems, the high-tension lines may form a network similar to an ordinary local distribution system.

Where synchronous condensers are not installed, the problem of the maximum amount of power which may be delivered through the system is similar to the simple resistance and reactance cases cited above in that additional load or shunt impedance simply alters the load and voltage in accordance with the relative impedances of the system.

The employment of synchronous condensers at the load centers or along the transmission lines to alter the power factor and maintain the voltage at the load materially increases the maximum amount of power that may be desired over a given transmission network. The theoretical maximum amount of power however, cannot be obtained under operating conditions because the synchronous equipment at the receiver drops out of step with the supply. Also, fluctuations in load will produce unstable conditions, which may accumulate sufficiently to cause the momentary swings in load to exceed the power limit, resulting in the receiver falling out of step with the supply at a lower load than it would under steady conditions. This is usually characterized as "hunting out of step."

In order to investigate the power limitations of a transmission system, it was necessary to rearrange and extend the present methods of transmission line calculations to make them more convenient for the study of the practical limit of maximum power. The method which has been found best adapted for this purpose is a development of the power circle diagram combined with the characteristic curves of the synchronous machines used to regulate the system. This power diagram has been made applicable to all the types of transmission systems by including the transmission line, step-up and step-down transformers, series and parallel circuits, so that the most complex transmission system may be represented by a single equivalent set of transmission constants. A general discussion of the methods of calculation, the maximum power limits, the practical operating limit and illustrated examples is given in Part I of the paper, and the analytical development upon which the discussion is based is given in Part II.

* * * * *

The Power Diagram for Transmission Systems

It has been found convenient in this study to represent the supply and receiver voltages and receiver loads of a transmission system by means of power circle diagrams,[1] such as illustrated in Fig. 1. A circle diagram may be defined as a graph of all receiver (or supply) loads that may be transmitted assuming definite supply and receiver voltages.

In order to plot the circle diagram, it is necessary to determine only three constants,[2] l, m and n which, when combined with the supply and receiver voltages selected, determine the centers and radii of the circles respectively for the assumed voltage conditions. It may be pointed out that the constant l is determined largely by the resistance of the circuit; the constant m by the reactance of the circuit; and the constant n by the impedance of the circuit.

Referring to Fig. 1, the circle diagram shows at once:

(1) The synchronous condenser kilovolt-amperes required at no-load, as indicated by the point x.

(2) The maximum load at unity power factor that

*Abridged from paper to be presented at the A. I. E. E. Mid-winter Convention, Philadelphia, Pa., February 4-8, 1924. Complete paper available without charge to members upon request.

1. A full analytical treatment of this diagram as applied to a complete transmission system is given in Part II. of the complete paper.

2. The significance of these constants is indicated in the appendix.

may be delivered for the particular voltage assumed, as indicated by the point y.

(3) The maximum power that may be delivered for the particular voltages assumed, as indicated by the point z.

The diagram readily permits the determination of the synchronous condenser capacity required for any particular load condition at the receiver; for example, in Fig. 1, circle a, the receiver load represented by the point U corresponding to 120,000 kw. real power and 74,000 kv-a. reactive power (corresponding to 85 per cent power factor), will require a synchronous condenser capacity represented by the line $U\ V$, or 85,000 kv-a.

Not only does the circle diagram permit representation of all receiver loads that may be transmitted for certain fixed supply and receiver voltage conditions, but it is readily adapted to represent changes in supply or receiver voltages. If the supply voltage only is varied, the radius of the receiver circle is varied in direct proportion, and the center of the circle is unchanged. In Fig. 1, the circle b represents the conditions with the supply voltage 10 per cent above that shown for circle a. If the receiver voltage only is varied, the radius of the receiver circle is varied in direct proportion and in addition, the center of the circle moves on the line $O\ C$ in proportion to the square of the receiver voltage. In Fig. 1, the circle c represents the conditions with the receiver voltage 90 per cent of that shown for circle a.

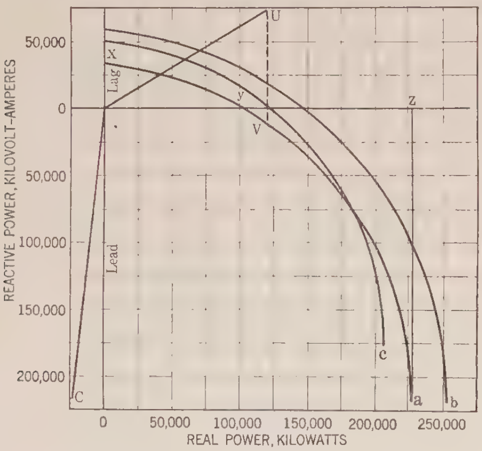

FIG. 1—CIRCLE DIAGRAM
a—$E_S = E_R$
b—E_S = 110 per cent E_R
c—E_R = 90 per cent E_S

For the majority of cases, the transmission supply voltage may be assumed constant, and this leaves only the receiver voltage and receiver load as variables. By plotting the power circles for receiver voltages from zero to more than 100 per cent of the supply voltage, it is possible to obtain a very complete picture showing how changes in receiver load affect the receiver voltage and vice versa. In Fig. 2, projection A, a family of such receiver power circles is plotted for various receiver voltages in steps equal to 10 per cent of the supply voltage. It will be observed that a curve can be drawn which will be tangent to the receiver power circles.[3] This curve is important in the study of maximum power limits, and will be designated as the "envelope" throughout this paper. It has not been shown on Fig. 2 as it would tend to obscure the circle diagrams. In Fig. 3, the envelope for the same transmission line as that plotted in Fig. 2 is shown together with the circle diagram for the receiver voltage equal to 100 per cent of the supply voltage.

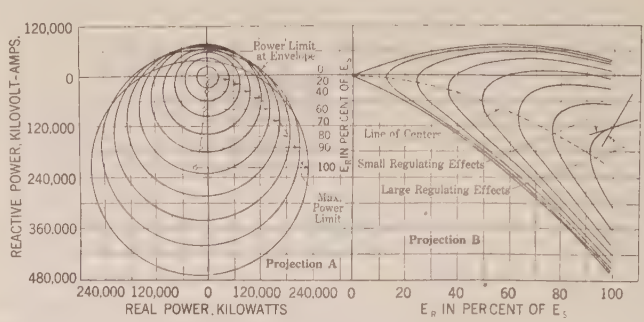

FIG. 2—VOLTAGE POWER DIAGRAM

Delivered power at a definite power factor is represented by a point in Fig. 3. If a point representing delivered power be selected within the envelope two power circles can be drawn intersecting at this point. This means that for any point within the envelope, there are two receiver voltages which will satisfy the receiver load and supply voltage conditions. For a point on the envelope, only one receiver voltage will satisfy the conditions, while for a point outside the envelope, there is no receiver voltage which will satisfy the conditions and consequently a point outside the envelope represents an imaginary operating condition. Therefore, the point at which any particular circle becomes tangent to the envelope is one type of power limit.

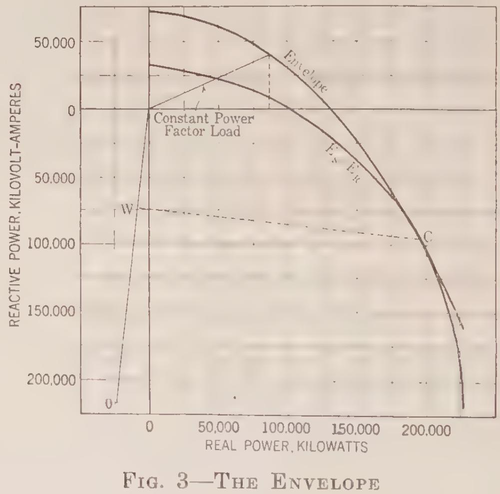

FIG. 3—THE ENVELOPE

3. An independent investigation has also been made by J. Ossanna, *E T Z* August 11, 1922.

To understand the true significance of the power circle diagrams, it is desirable to conceive of them as a three dimensional figure, that is, considering the supply voltage constant, the general equation representing the kilovolt-amperes delivered involves just three variables: The receiver power, the receiver reactive power, and the receiver voltage, which may be plotted along the X, Y, and Z axes, respectively, By virtue of its construction, the surface of the figure represents all possible voltage-power conditions with a constant supply voltage. Fig. 2 has been plotted to show two projections, A and B, of the voltage-power surface; projection A shows the projection on the X-Y plane of intersections of the surface with planes parallel to the X-Y plane passing through points representing receiver voltages of 10 per cent, 20 per cent and so on of the supply voltage. Projection B shows the projection on the Y-Z plane of intersections of the surface with planes parallel to the Y-Z plane passing through points representing 0-kw, 30,000 kw., 60,000 kw. and so on.

Theoretical Maximum Power Limit

Heretofore, it has been the general practise of transmission engineers to consider only one circle diagram or one set of voltage conditions in their calculations, without relating the solution generally to other circle diagrams or calculations representing other voltage conditions. The study of these relationships is facilitated by the graphical conception of a surface which may be represented by an actual model.

The receiver load at any constant power factor may be considered as an impedance connected across the circuit, and if this impedance is varied from infinity to zero, the receiver load increases to a maximum and then decreases to zero. This is shown graphically by the line for constant power factor load in Fig. 3 with the maximum amount of power determined by the envelope.

If synchronous apparatus is available at the receiver for maintaining the voltage and controlling the power factor, the power limit may be increased. With infinite capacity in synchronous apparatus available, the power limit is that determined by the vertical tangent to the receiver circle for the voltage assumed.

Study of the voltage-power surface has developed some very interesting features which are associated with the performance characteristics of the synchronous apparatus used to regulate the system. These features will be further discussed in a subsequent section. For the time being the maximum limits may be considered as falling into two classes:

First: The power limit defined by the envelope for any given power factor of load and resulting voltage conditions. The load will include all kinds of electrical equipment, but if it includes any rotating equipment, this will fall out of step if the voltage drops sufficiently, or reduce load by a drop in speed if sufficient torque is still available when the power limit is passed.

Second: The power limit defined by the vertical tangent to the circle diagram. In addition to the load, synchronous apparatus is required to regulate the voltage-power conditions up to the maximum power point when the receiver will pull out of synchronism with the supply end.

For purposes of illustration, these two power limits have been identified on Fig. 2, the power limit for any given power factor being marked the "Power Limit at the Envelope," and the power limit described by a vertical tangent, the "Maximum Power Limit."

Practical Maximum Power Limit

The usual high-voltage transmission problem involves a regulated system with synchronous machines of limited capacity and commercial design. The Practical Maximum Power Limit, therefore, lies between the limits for an unregulated and a regulated system with infinite condenser capacity, that is, between the power limit at the envelope and a vertical tangent to the receiver circle. The characteristics of the synchronous machines which affect the power limit of a transmission system include not only the capacity in kilovolt-amperes, but also the regulating effect. By "regulating effect" is meant the change in reactive kilovolt-amperes for a definite change in voltage, the greater the change in reactive kilovolt-amperes, the greater the regulating effect. The relation of the characteristics of synchronous machines to the power limits of a transmission system is indicated by the curves of regulating effect of loads sketched on Fig. 2.[4]

In general, the discussion of the envelope and maximum power limit should be considered with a large transmission system, or in connection with the synchronizing stability of short lines between power stations where large loads are momentarily thrown on the tie lines so that they exceed the power limits and the stations fall out of synchronism. In this connection, it may be noted that a short circuit on the secondary system may be considered as a shunt loading on the transmission system and the corresponding circle diagram obtained on this basis.

Effect of Transmission Design on the Power Limits

The methods for increasing the Practical Maximum Power Limits of transmission systems will next be considered. These methods may be divided into two classes:

(1) Those which increase the power limits as determined by the envelope and the vertical tangent to the receiver power circles, and

(2) Those which permit stable operation at points closer to the maximum power limit.

The first class depends upon the modification of the circuit constants of the transmission line or increasing

4. "The Limitations of Output of a Power System Involving Long Transmission Lines" by E. B. Shand.

the transmission voltage, so that the power limits are actually increased. The second class is dependent upon the characteristics of the rotating machinery in the load, as discussed in a companion paper.

The relation between the circuit constants of the transmission line which will give the maximum power limits, has been analyzed in Part II of the complete paper. The results of this analysis show that for long transmission lines the l constant should be small, and the n constant large; and for short transmission lines, that the resistance should be made as small as practicable, and that the reactance be equal to $\sqrt{3}$ times the resistance. It becomes necessary, therefore, to distinguish between the cases where the reactance of the transmission line is large or small in comparison with the resistance. In general, the reactance of a transmission circuit will decrease very slowly with increase in conductor size, whereas the conductivity increases directly. Consequently, for large capacity, high-voltage circuits, the reactance becomes several times the resistance, and this case will be considered first.

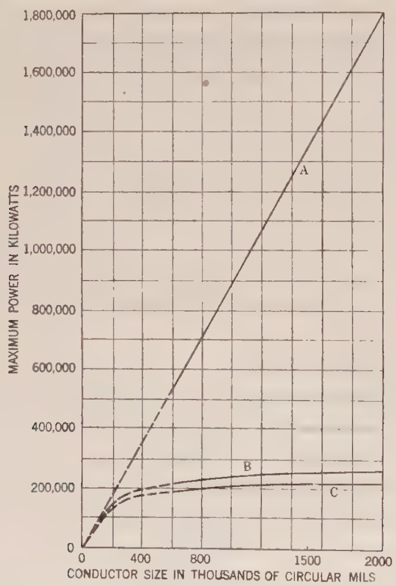

Fig. 4

In general, the power limits of a transmission system are increased by the use of larger conductors or increased voltage. Curves B and C of Fig. 4 show the two power limits for a group of 3-phase, 60-cycle transmission lines, 250 miles in length, operated with 220 kv. at both supply and receiver ends. It will be noted that the increase in size of copper conductor from 600,000 cir. mils to 2,000,000 cir. mils only increases the maximum power limit about 20 per cent. Therefore, it is apparent that the conductor size should not be increased indefinitely, except to reduce economically the power loss consistent with the increased cost of line. In a high-voltage transmission system, the corona effect may require a conductor size above which no appreciable gain in power limits will be obtained.

Curve A of Fig. 4, has been plotted as a matter of interest to show the effect of reactance on maximum power limits. With small conductor sizes, the resistance is the determining factor of the power transmitted, so that all limits approach curve A, but with increased conductor size and limited receiver voltage the power transmitted is determined by the reactance, so that for large conductor sizes, there is a very large difference from curve A.

One method for increasing the power limit of a single circuit involves the use of a divided conductor. The arrangement would be similar to that proposed by Percy H. Thomas in a discussion on the "Critical Load"[5] of a transmission line. The increase in the power limit that may be accomplished by this method is determined by the limitation in the separation of the individual conductors due to the formation of corona.

Conductor spacing has an important effect on the power limits; the closer the spacing, the greater the power limits. However, variation in the spacing of conductors is not a practical method of increasing the power limit, for the reason that the closest spacing consistent with the avoidance of interruption to service and possible operation at higher voltages in the future, will always be employed.

The case in which the reactance of the transmission conductor is small in comparison with the resistance rarely occurs with 60-cycle power supply, except possible with low voltage, small capacity circuits, or an underground cable system. With 25-cycle power supply, however, this condition is likely to occur with moderate capacity systems. The conditions for obtaining the maximum amount of power in this case require that the resistance be made as low as practicable, and that the reactance be increased to equal $-\sqrt{3}$ times the resistance. Hence, in this particualr case, increased spacing of the transmission conductors or the use of reactors with underground cable would result in increasing the power limits of the circuits.

The ratio of the resistance to the reactance of a transmission circuit has an interesting effect on the power limits. If the load on a transmission circuit operating under constant voltage conditions is increased from no-load, the receiver loads follow along the circle diagram, passing through the point of tangency with the envelope, and through the point of maximum power. If the reactance of the transmission circuit is several times the resistance, the power limit at the envelope is reached before the maximum power limit; on the other hand, if the reactance is small in comparison with the resistance, the power limit is reached first. Consequently, for transmission circuits having a low ratio of reactance to resistance, the special regulating

5. Percy H. Thomas, A. I. E. E. Transactions, 1910.

characteristics of synchronous machines become unimportant.

The frequency of the power supply has an important effect on power limits, particularly for the transmission of large amounts of power where high voltage and large capacity circuits will be employed. For such conditions, the 60-cycle reactance is many times the resistance and the use of a lower frequency, for example, 25 cycles, would reduce the reactance and increase the power limit by more closely approaching the theoretical conditions for transmitting the maximum amount of power with a given conductor. The maximum power limit for a 250-mile transmission line with 636,000 cir. mil aluminum conductors is shown in Fig. 5, with curve *B* showing the power limit for 60 cycles, and curve *D* the corresponding power limit for 25 cycles.

The effect of considering the reactance of transformers has not been mentioned previously. It is evident from the preceding discussion that the addition of the reactance of transformers might increase the power limit for certain conditions, particularly on moderate capacity, 25-cycle systems. On the other hand, for high-capacity, high-voltage systems, such as the 220-kv., systems which have been proposed the addition of the transformer reactance will decrease the power limits appreciably.

Within the last few years, the idea of a loaded transmission line has been developed. By this means, it is possible to obtain equivalent transmission constants which are more favorable for the transmission of power than those that could be obtained by modification in transmission line conductor spacing, arrangement or size. With a loaded transmission line, it is proposed to install at intervals a "lumped" impedance connected either in series or in parallel with sections of the "smooth" transmission line. For the condition in which the reactance of a short transmission line is less than $-\sqrt{3}$ times the resistance, the power limit will be increased by adding series reactors connected at intervals in the transmission line, as proposed by R. A. Philip.[6] The method of series loading with inductance, however, is of very limited application, because with the usual transmission problem, the reactance is already in excess of the desired amount.

The use of shunt loading with synchronous machines was proposed in a paper before the A. I. E. E. in 1921, by F. G. Baum. This method of loading for increasing the power limits is, in effect, one of variable shunt capacity. The effect of loading a transmission line with intermediate synchronous condensers which are controlled so as to maintain constant voltage at these points, is to increase the power limits of the system as a whole to the power limit for the individual sections. In other words, a 500-mile transmission line with one intermediate loading point, in effect increases the amount of power that may be transmitted to that of a 250-mile section. In Fig. 5, curve *B* shows that the maximum power limit with 220 kv. at the supply and receiver ends of a 3-phase, 60-cycle, 636,000-cir. mil aluminum conductor transmission line is about 120,000 kw. for the 500-mile line, and about 180,000 kw. for the 250-mile line. Consequently, a loaded transmission line, 500 miles in length, would be capable of delivering 180,000 kw. less a small amount for losses in the second 250 miles section of the line.

6. R. A. Philip, "Economic Limitations," A. I. E. E. TRANSACTIONS, 1911. This proposal was based on short lines as the effect of capacity was neglected.

EXAMPLES OF HIGH-VOLTAGE TRANSMISSION

From an engineering standpoint, it is practically impossible to predict the limits which high-voltage transmission will reach. However, from a commercial viewpoint, 220 kv. and certainly not more than 330 kv. will meet our requirements for some time to come, as good operating practise will limit the amount of power which should be entrusted to a single circuit. As the power systems grow, these limits will be raised, but this will be a process of considerable development.

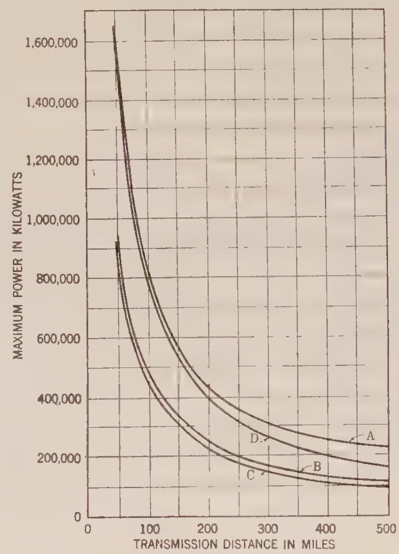

FIG. 5

Assuming a tentative standard of 220 kv. as the present highest transmission voltage, it is interesting to note the characteristics of different lengths of lines. It has been pointed out in Fig. 5 that the power limit is rapidly reduced by increased distance so that considerably more power can be carried by making up a long line of several sections with synchronous condenser loading at intermediate points.

In order to bring out quantitatively the present limits of high-voltage transmission, three examples are worked out which also show the advantage of loading a transmission circuit. The results of these calculations are shown in Fig. 6, 7 and 8 which give the circle diagrams for 250, 500 and 750-mile lines respectively. The circle diagrams have been plotted for three voltage conditions so as to indicate the general shape of the diagram with respect to the voltage power surface.

The supply power circle diagrams corresponding to the receiver power circle diagrams are also plotted.

Comparison of the circle diagrams, Figs. 6, 7 and 8, shows how the voltage power surface is changed with respect to the operating range. For the longer lines, the operating range is at lagging power factor. This imposes a severe requirement on the characteristics of the regulating equipment, since it must be designed for heavy lagging load, and hence high reactance when, in order to obtain maximum stability the machine should have minimum reactance.

From a general consideration of the characteristics

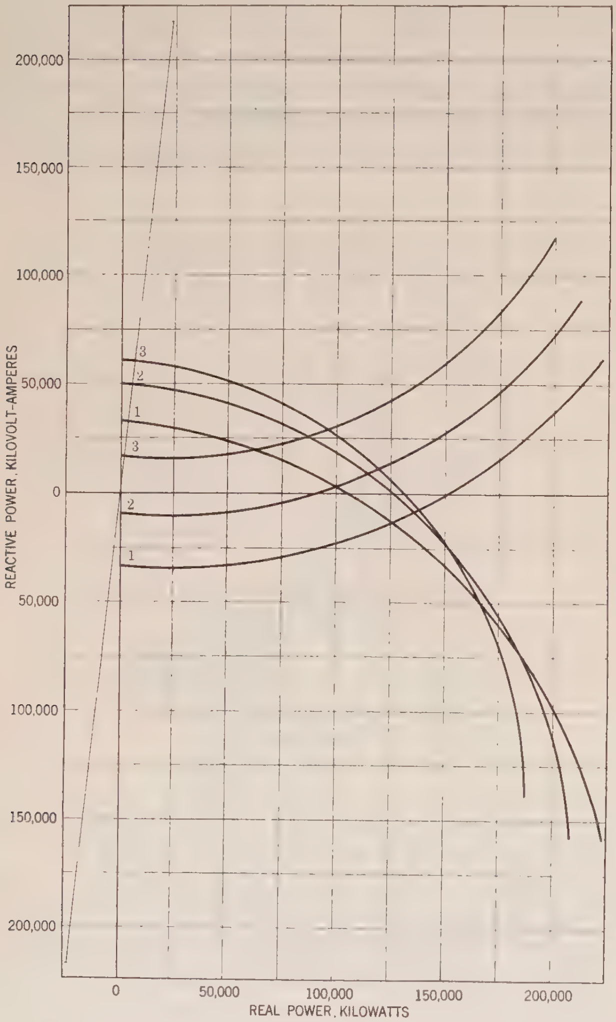

FIG. 6—CIRCLE DIAGRAM FOR 250-MILE LINE
1—E_R = 100 per cent E_S
2—E_R = 90 per cent E_S
3—E_R = 80 per cent E_S

of the line, it is apparent that the longest transmission section of a line should not exceed 250 miles, and shorter sections would be preferable to obtain a higher average power factor, and hence lower losses at all loads, and a considerable increase in the power limits and general stability of the system. Based on the economic number of loading points, it is estimated conservatively that 135,000 to 150,000 kw. per circuit can be transmitted from any existing power supply to a load center with equipment commercially available.

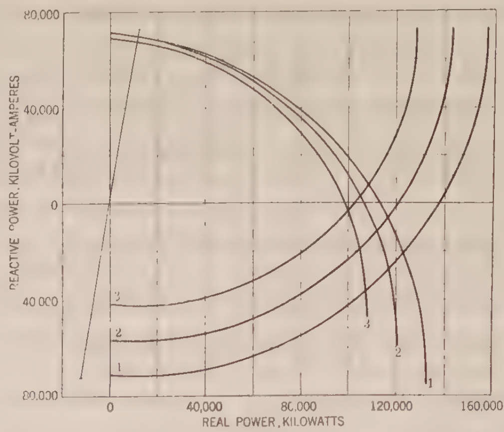

FIG. 7—CIRCLE DIAGRAM FOR 500-MILE LINE
1—E_R = 100 per cent E_S
2—E_R = 90 per cent E_S
3—E_R = 80 per cent E_S

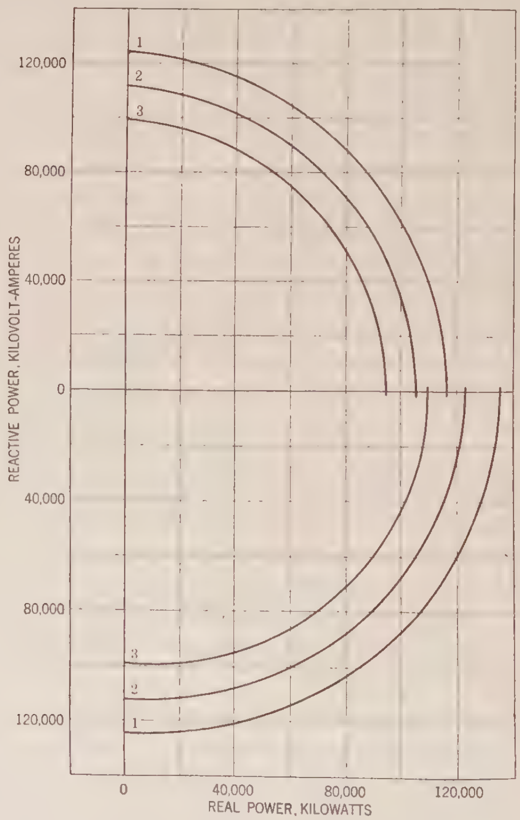

FIG. 8—CIRCLE DIAGRAM FOR 750-MILE LINE
1—E_R = 100 per cent E_S
2—E_R = 90 per cent E_S
3—E_R = 80 per cent E_S

CONCLUSION

To recapitulate on the points of general interest in transmission system design, there are several items to be considered.

1. Methods of calculation have been developed

in the power circle diagram which accurately determines the maximum power limits under various circuit and electrical conditions.

2. Two types of power limits have been discussed with their relation to the load and regulating equipment.

3. Methods of increasing the power limits have been discussed in transmission design.

4. On the basis of economy and stability of operation, it is recommended that a single section of line be less than 250 miles, and longer lines loaded at intermediate stations with synchronous condensers so that no section exceeds 250 miles.

In concluding, it is important to note the general application of the methods developed to any transmission layout and to the determination of the load capacity or synchronizing capacity between stations in studying the performance of a system.

Appendix

In a transmission the relation between supply and receiver phase voltages and receiver current may be expressed in the following form:

$$\dot{E}_r = A_0 \dot{E}_s + B_0 \dot{I}_r \qquad (\mathbf{1})$$

where A_0 and B_0 are constants depending upon the characteristics of the circuit. For a smooth transmission line

$$A_0 = \cosh \sqrt{Z\,Y}$$

$$B_0 = \sqrt{Z/Y} \sinh \sqrt{Z\,Y}$$

where Z = series impedance per mile of transmission line and Y = shunt admittance per mile of transmission line and l = length of line in miles. A method for obtaining the value of circuit constant for complicated network is given in Part II of the complete paper.

From equation (**1**) may be derived the following in expression in terms of receiver power, supply and receiver voltage

$$(P_R + l\,E_R)^2 + (Q_R + m\,E_R)^2 = n^2\,E_R^2\,E_S^2 \qquad (\mathbf{2})$$

This equation is in the form of a circle with the coordinates of the center at the points $-\,l\,E_R^2$ and $-\,m\,E_R^2$ and whose radius is $n\,E_R\,E_S$. In the equation (**2**) E_S and E_R are supply and receiver line voltages, and P_R and Q_R are the total receiver real and reactive power respectively.

The value of l, m and n constants in terms of A_0 and B_0 are as follows:

$$l = \frac{A_0\,\bar{B}_0 + \bar{A}_0\,B_0}{2\,B_0\,B_0}$$

$$m = \frac{A_0\,\bar{B}_0 - \bar{A}_0\,B_0}{2\,B_0\,\bar{B}_0}$$

$$n = \frac{1}{B_0\,\bar{B}_0}$$

In the above expressions $\bar{A}_0$ and $\bar{B}_0$ are conjugates of $\bar{A}_0$ and $\bar{B}_0$ respectively, which constants are defined by equation (**1**).

THEORY AND PERFORMANCE OF ELECTROLYTIC RECTIFIERS

The demand for small rectifiers has grown during the last few years because of the increasing use of small portable storage batteries requiring low charging currents and also because of the increasing practise of charging larger batteries at low rates, known as "trickle charging." On account of this growing use and the general lack of information about the performance of such rectifiers the Bureau of Standards undertook a study of their comparative efficiencies under different conditions of service.

The characteristics of the electrolytic rectifier make it suitable for such purposes as the charging of batteries for radio sets, and this has resulted in the appearance of several different forms of the aluminum and tantalum rectifier.

The operation of the electrolytic rectifier was found to depend upon the electrical characteristics of the circuit as well as upon the rectifier itself. In order to explain the effect of the characteristics of the circuit upon the wave form of the rectified current as observed by the oscillograph, it was necessary to make a thorough study of the mathematical theory of rectification. The principal factors studied were the effect of inductance with and without iron cores, capacity of the rectifying electrode and the counter electromotive force of the battery being charged, as they affect the energy efficiency, power factor and the ratio of average current to the root mean square value as well as the wave form of the rectified current. Numerous oscillograms were made to show the effect of each of the factors. This material is being prepared for publication but some additional experiments are necessary before the paper can be completed.

REVISION OF NATIONAL ELECTRICAL SAFETY CODE

The current edition of the National Electrical Safety Code is being revised according to the Rules of Procedure of the American Engineering Standards Committee. The revision of Part 2 dealing with underground and overhead line construction was started last year and is being handled by a large Sectional Committee and eight sub-committees. The same Sectional Committee will consider changes to Part 4.

The other parts of the Code, which deal with interior work and with grounding, will be handled by a separate Sectional Committee which is now being organized. Anyone having suggestions for change in these parts of the Code should submit them at once to the Bureau of Standards, Washington, D. C., for consideration.

Variable Voltage Control Systems as Applied To Electric Elevators

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Review of the Subject.—*Low-speed electric elevators, using d-c. motors, came into use about 1890. Later, a-c. motors were employed, but on account of the difficulty of speed control could not be used for the high speeds necessary in tall buildings. Since the height of buildings is dependent upon the elevator system, and in many districts only a-c. is available, the need for high-speed equipments that can be operated from a-c. is evident. A solution to the problem is found in the variable voltage system of control.*

In this system each elevator motor is supplied by an individual generator driven by a motor operating from the a-c. or d-c. supply voltage. The generator's voltage, and hence the elevator motor's speed, are controlled by varying the field of the generator.

The apparatus consists of:

1. An ordinary shunt-wound d-c. elevator motor.

2. A d-c. generator of special design for the elevator motor.

3. Control panel for the generator and elevator motor.

4. An a-c. or d-c. motor to drive the generator.

5. A starting device for the driving motor

And if the supply is a-c.

6. A direct-connected exciter for the field, brake and control circuits.

The control panel (1) makes the proper connections for up and down motion of the car; (2) releases, or sets, the brake: (3) controls the speed; (4) discharges the generator field during retardation, and on stopping (5) demagnetizes the generator and (6) opens the circuit between the armature of the generator and the armature of the elevator motor.

From tests the following conclusions in favor of the variable voltage over the rheostatic control system are drawn:

1. Speed.—*High-speed installations are now possible for any commercial a-c. voltage and frequency.*

2. Acceleration and Retardation.—*The rate of acceleration increases gradually to about half speed, then decreases uniformly until full speed is reached. The time and power required for acceleration are less than with rheostatic control. The time remains practically the same for all loads. The higher rate of acceleration and retardation permits higher speeds, and the smoothness, besides reducing wear and tear on the machinery, makes riding entirely comfortable to passengers. The impression of falling which is often given, under rheostatic control, by a heavily loaded car when descending, is inherently avoided, since the car speed follows the generator voltage which at no time changes suddenly.*

3. Speed Control and Regulation.—*The speed regulation remains flat at as low as one tenth full speed. Consequently it is easier to make an accurate landing, fewer false stops are made the car may be "inched" easily and quickly. In stopping, regenerative braking is set up which brings the car quickly but smoothly to a low speed before the friction brake is applied. Positive speed control enables the limit stops to be made in less time and shorter distances, and without over-travel.*

4. Efficiency and Economy of Power Consumption.—*Less power is required in acceleration and retardation. This saving of power over the rheostatic control is greatest when the number of starts and stops is large. Power is returned to the line while making the limit stops. Power consumption is not increased in making small movements of the car or in running at low speed. During idle periods standby losses may be eliminated by shutting down the motor generator set.*

5. Maintenance.—*Since the switching of major currents is eliminated and they are controlled indirectly, the number of arc rupturing contacts is reduced to a minimum the control as a whole is simpler, less adjustments are necessary and maintenance costs are lowered.*

6. Safety.—*Inherent safety features make higher speeds possible. Limit stops are made accurately and positively. A second independent means is provided for stopping the car in emergencies. On failure of power a dynamic braking circuit closes and a field is maintained, on the elevator motor, making certain the stopping of the car. An overspeed contact on the motor generator set opens the safety circuit independently of the speed governor.*

THE application of electric power to elevators dates back to 1890. The early motors were direct-current machines and were applied to relatively low-speed elevators. Later a-c. motors came into use, both phase-wound and cage-wound secondaries being used. Higher-speed elevators were developed as building heights increased. The modern sky scraper would not be practical except through the use of high-speed elevators. The d-c. motor and its controller were perfected for high-speed work largely because of the difficulty in controlling the speed of the a-c. motor. Until quite recently high-speed elevators invariably required the use of d-c. power.

In the last three or four years a great deal of engineering effort has been put into the problem of developing a high-speed a-c. elevator equipment. These efforts have been very fruitful and a-c. power can now be applied to elevators at as high a speed as can d-c. One of the a-c. systems that has recently been perfected is known as variable voltage. It is this system that will be described in this paper. The development of this system has also greatly improved the operation of all classes of elevators to which it has been applied and because of its superior operation and high economy has frequently been used on d-c. power lines.

During the last few years the cost of buildings and the ground upon which they are built has increased so rapidly that effective use must be made of every available square foot of floor space. The space occupied by the elevators brings in no direct income and should be reduced to a minimum. Higher car speed and reduction of lost time due to better control offer considerable help in solving this problem. Variable voltage control has been used very successfully for elevators running at speeds as high as 700 feet per minute. The system with further refinements in some details will no doubt be used for still higher speeds in the future.

I. Requirements of Elevator Service

It is not the purpose of this paper to discuss all the factors that go to make up elevator service. Elevator

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service is, however, so affected by the kind of electrical equipment installed that in discussing any particular control system for elevator work, it will be necessary to consider its fundamental requirements. The requirements of elevator service that are affected by the electrical equipment and particularly the control may be enumerated as follows:

1. *Elevator Speeds.* The speed at which cars are run affects the service, and is very largely dependent upon the electrical equipment used and upon the control that can be obtained. Low-speed elevators require relatively simple equipment, while the maximum speed that can be used is limited by the control systems in use at the present time, and increases in speed are probably dependent upon further control developments.

2. *Acceleration and Retardation.* The rate of acceleration and retardation has a very marked effect upon elevator service, not only in so far as comfort to the passengers is concerned, but it also has a direct bearing upon the speed at which cars can be run. It is mostly dependent upon the control system and the ideal control system is one which will accelerate and retard the car at the highest possible rate, and still operate so smoothly as to subject the passengers to no discomfort.

3. *Speed Control and Regulation.* Elevator speeds in the past have increased directly as methods of increasing the speed range over which motors could be controlled have developed. No matter how high a car speed is used, the speed from which the landing can be made will remain more or less fixed. The regulation of the equipment affects elevator service because if the cars slow down too much under load the service is slowed up at the very time when maximum service is demanded.

4. *Efficiency and Power Consumption.* Electrical elevator equipment at the present time has reached a high stage of development and the matter of economy in operation probably receives more attention than in almost any other industry. Electrical elevator equipment to give good service must not only handle passengers as quickly and smoothly as possible, but it must also do it in an economical manner.

5. *Upkeep and Maintenance.* Upkeep and maintenance constitutes a considerable item in the cost of elevator service. It is, therefore, desirable that this item be kept as low as possible. It has an even more important bearing upon the continuity of service. Equipments that are easy to maintain and which are readily kept in good condition are much less subject to shutdown than those which require constant attention to keep them in operating condition.

6. *Safety.* Although this item appears last in the list it is far from being the least in importance. In fact safety is the first consideration in giving good elevator service. Any developments in control systems or apparatus which increase the service must at the same time be absolutely safe in operation, and in no case must the safety of passengers be jeopardized in order to save time or reduce the first cost of installation. Any control system having features which increase the safety with which passengers can be handled is worthy of serious consideration from that standpoint alone.

II. Description of the System

The variable voltage system consists of five main elements, a d-c. motor to drive the elevator, a d-c. generator for each elevator motor, an a-c. or d-c. motor to drive the generator, a control panel for the elevator motor and generator and a starting device for the motor driving the generator. If the supply is a-c., a direct-connected exciter is added. The auxiliary equipment, such as the car master switch, limit switches and magnet brake may be the same as those used for

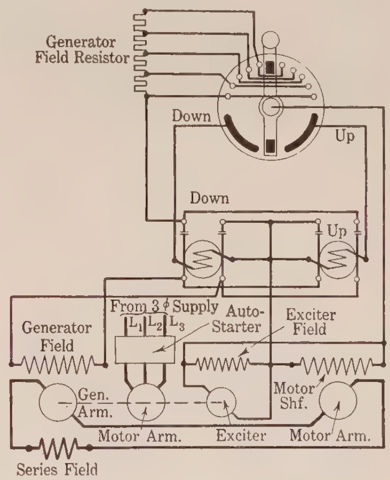

Fig. 1

Elementary diagram showing principal connections of variable voltage control system. The generator is driven by an a-c. motor and the set has a direct-connected exciter.

other well known systems of control. Fig. 1 is a schematic diagram showing how the apparatus is connected together.

1. *Elevator Motor.* The elevator motor requires no special features and is shunt wound which is the accepted elevator practise. No speed adjustment by field control is necessary although it is good practise to strengthen the field during the starting period for applications where high starting torque is required. A constant-speed motor for a given rating will have a lower weight and cost, and better electrical performance than the corresponding adjustable-speed motor.

2. *Generator.* The generator is one of the most important units of the system and is designed almost entirely from the standpoint of its control functions. As shown in the schematic diagram the motor and generator armatures are connected directly together electrically without the use of any resistors. The direction of rotation and the speed at which the elevator motor runs depend upon the direction and value of the generator voltage. The field magnet is excited from a separate source and the field excitation is governed by the controller.

The generator has commutating poles and sufficient commutator capacity to take care of the current peaks that must be handled during the accelerating period. High efficiency and good voltage regulation are incorporated as essential features. Fig. 2 shows the performance curves of a 25-kw. machine that are typical of what can be obtained. The efficiency reaches a maximum of 89 per cent and remains high with overloads so that acceleration is accomplished without excessive generator losses.

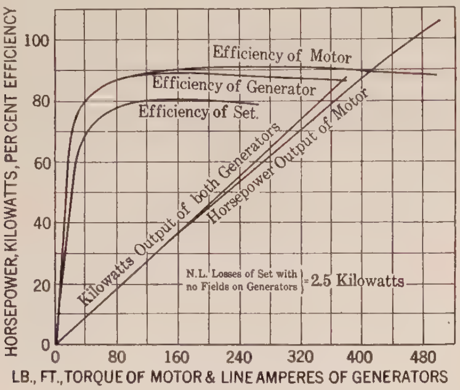

Fig. 2

Performance curves of a double generator motor generator set with an a-c. driving motor.

Fig. 3 shows a test on the rate of building up of a 25-kw. generator designed for variable voltage control service. Full excitation voltage was thrown on the field coils in one step. The machine builds up to 85 per cent of its final voltage in 1¼ seconds and in 2½ seconds is generating full voltage. Curve 2 shows the effect of a short-circuited damper winding on the field poles. The damper winding has the effect of increasing the time constant of the field at the early stage of building up but does not materially affect the total time of building up. Practical use of this characteristic of the field coils can be made in giving the proper shape to the acceleration curve.

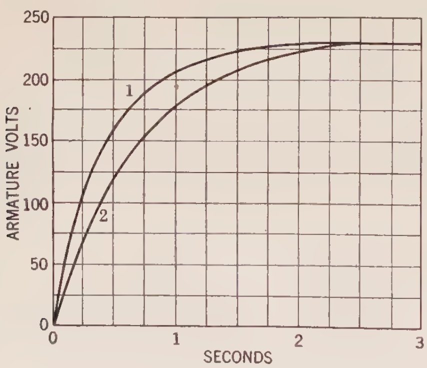

Fig. 3

Curves showing the rate of building up of generator voltage. The curves show the effect of a short-circuited damper winding on the field poles. The maximum rate of acceleration can be adjusted by changing the resistance of this damper winding.

3. *Driving Motor of the Motor Generator Set.* The driving motor of the set may be either a-c. or d-c. depending upon the character of the power supply. Alternating-current motors are cage-wound and designed for low slip and high efficiency. Direct-current motors are shunt wound. It is of particular importance that the no-load or idling losses be kept as low as possible. The motor generator set whose performance curves are shown in Fig. 2 has a no-load loss of 2.5 kw. or 1.25 kw. per elevator.

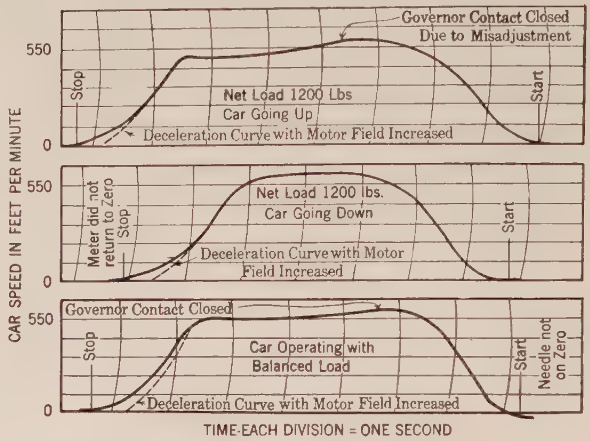

Fig. 4

Oscillogram showing armature current and current in the extra and standing Motor Fields.

4. *Motor Generator Set Starter.* Since the motor generator sets are started infrequently and always start without load a relatively simple automatic starter may be used. For d-c. motors a counter e. m. f. starter with two or three steps of light duty starting resistance is used. The only special feature required

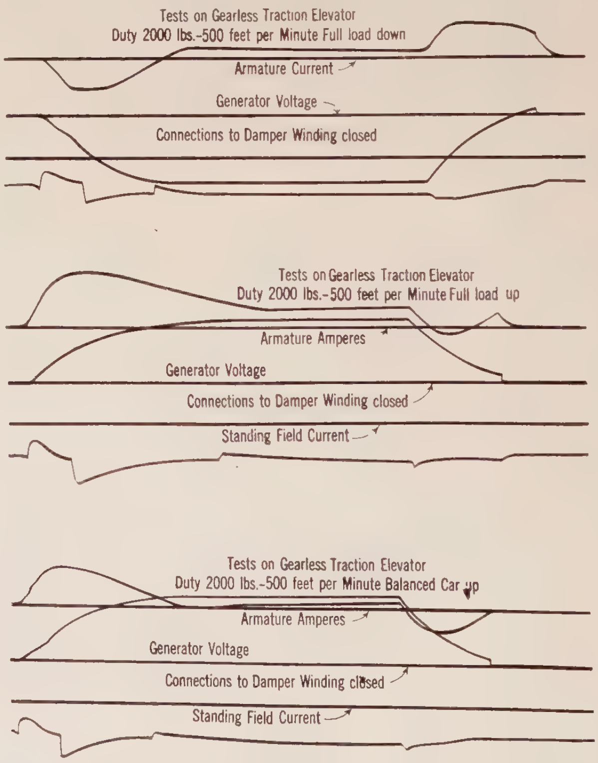

Fig. 4-A

Oscillogram showing armature current, generator voltage, and standing field current.

is a counter e. m. f. relay interlocking with the elevator controller to prevent energizing the generator field and brake circuits when the motor generator set is not running or before it has come up to speed. For the a-c. sets a resistance type starter is used. Alternating-current sets have a direct-connected exciter and a switch controlled by the voltage of the exciter is used to short circuit a step of primary resistance when the motor has come up to speed. No interlocking relays are required since there will be no voltage to energize the d-c. circuits unless the motor generator set

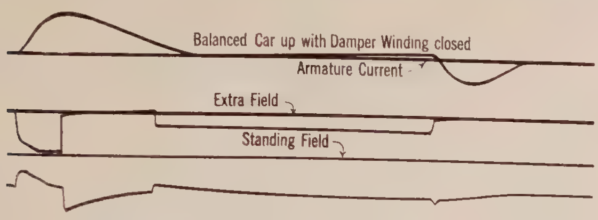

FIG. 5

is running. Reverse phase protection is inherent in the combination without the use of relays because the exciter being a self-excited machine will not build up its voltage if the motor generator set is started in the wrong direction.

5. *Elevator Controller.* The elevator controller proper carries the contactors and relays to perform the following primary functions:

1. Connect the generator field to the excitation

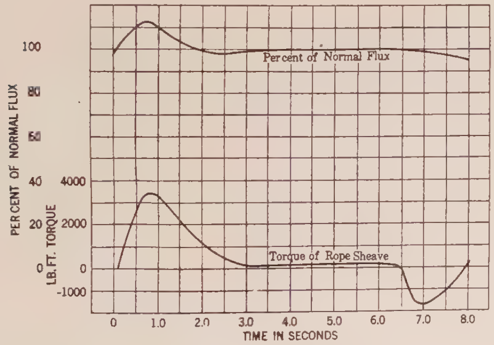

FIG. 5A
Curves showing motor field flux and torque.

voltage in the proper direction for up or down motion of the car.

2. Energize the brake coil. The brake coil is opened on both sides and is fed through the same contactors that energize the generator field.

3. Control the car speed by controlling the excitation of the generator field.

4. Provide the proper discharge circuits for the generator field during retardation.

5. Connect in an extra demagnetizing field on the generator in stopping.

6. Open the connection between the generator and elevator motor after the car has come to rest.

7. Control the setting of the brake by means of its own self induction and so obtain a smooth stop.

There is only one contactor carrying armature circuit current. This contactor is included as an additional safety measure and in normal operation opens only after the car has completely stopped and the brake has set. It also opens immediately when the safety devices, such as the car emergency switch, overspeed governor, etc., operate. In normal operation no current is ruptured by this contactor. The other contacts on the controller handle only field, brake and control circuit currents. When the armature circuit contactor opens its back contacts close a low-resistance dynamic-braking circuit for the elevator motor. This contactor has auxiliary contacts through which the brake coil

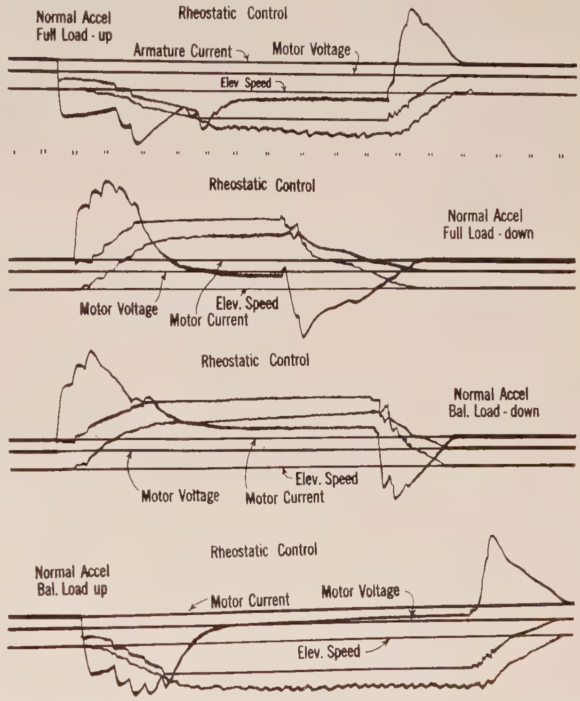

FIG. 6
Accelerating characteristics of a gearless traction elevator with rheostatic control.

current passes so that the brake cannot be released unless the armature circuit is closed.

III. CHARACTERISTICS AND OPERATION

1. *Acceleration and Retardation.* To obtain maximum service from an elevator car it should be accelerated and retarded at as high a rate as possible without discomfort to passengers. The uncomfortable feeling frequently experienced while riding in high-speed elevators is not due to a high rate of acceleration but to rapid changes in the rate of acceleration. Therefore the rate of acceleration should not change suddenly during the accelerating period.

When a fully loaded car is to be accelerated in the down direction the weight of the unbalanced load alone is sufficient to accelerate the car. Under a system of

rheostatic control, if the motor is now connected to the line with a resistance in series with its armature, the voltage impressed on the armature will be reduced only by a flow of positive current in the resistance current flowing to the motor from the line being regarded as positive; current returned from the motor, acting as a generator, to the line, as negative. This current if it passes through the motor armature would increase the accelerating torque to a value which would be very uncomfortable to passengers. It is therefore customary to connect resistances in parallel with the motor armature so that a voltage drop can be produced in the armature series resistance and retard the acceleration. This is very uneconomical and accomplishes the desired result imperfectly so that it is quite a common experience to ride in cars which give one the sensation of falling when descending heavily loaded.

The acceleration is considerably affected by the load and there is a considerable difference in the shape of the speed-time curves obtained with different loads. With full load up the car accelerates too slowly and with full load down the acceleration increases too rapidly for comfort. The rate of acceleration increases very rapidly when the motor is first connected to the line and when each step of resistance is short-circuited.

With variable voltage control it is possible to obtain more uniform accelerating and retarding characteristics under widely varying load conditions. The generator voltage builds up uniformly, following a fixed law and the car speed follows the generator voltage. The torque developed by the motor may be either positive or negative depending upon the load, but the speed in all cases depends upon the voltages generated by the machines.

If the car is to be stopped from high speed in a minimum of time, the maximum rate of retardation must be maintained during nearly the whole retarding period. When the controller handle is moved to the low-speed point resistance is connected in series and parallel with the generator field. The field shunt or discharge resistance can be adjusted if the generator field has the proper time constant, so as to give the car exactly the right rate of retardation. As the field dies down the generator voltage falls below that of the elevator motor and regenerative braking brings the car to a low speed. The generator voltage falls with absolute smoothness and there are no steps as in the case of rheostatic control. The application of dynamic braking in steps produces peaks in the rate of retardation that tend to cause the cables to slip so that the average rate of retardation must be kept well below the peaks. The absence of these peaks makes it possible to keep the average rate of retardation very high.

Electrical or regenerative braking is used to bring the car to a very low speed from which the final stop can be made with a friction brake. The transition from electrical to friction braking is perfectly smooth as a result of the characteristics of the electrical system and the method of controlling the friction brake.

The friction brake is a very important factor in making a smooth stop. It does not help matters much to have the retardation perfectly smooth if the final stop produced by the brake is rough or if the car slides a considerable distance after the brake sets. Electrical braking will reduce the speed of the car to a low value but except under certain load conditions will not bring it to a complete stop. It is, therefore, only necessary to apply the brake in such a manner that an abrupt change in the rate of retardation is not produced.

The distance that the car will slide when the friction brake sets is given by the formula:

$$d = (K_1 M_1 + K_2 M_2) \frac{V^2}{T_B + T_L} \qquad (1)$$

See appendix for symbols.

Equation 1 shows that the slide of the car when the brake sets varies as the square of the speed and inversely as the net torque exerted by the brake. The net torque developed by the brake is the algebraic sum of T_L and T_B. The torque of the load T_L assists the brake to stop when the load is positive or is being hoisted. It acts against the brake when the load is being lowered and increases the slide. The velocity of the car at the time when electrical braking becomes ineffective, however, has the greatest effect on the distance the car will slide through the brake since the slide varies as the square of the velocity. It is evident therefore that for minimum slide the car speed should be as low as possible before the friction brake is called upon to stop it.

To avoid a jar when the final stop is made there should be a smooth transition from the retardation produced by electrical braking to that developed by the friction brake. To accomplish this result it is necessary to apply the friction brake gradually so that full braking torque is not exerted instantly. The brake must be designed and adjusted so as to stop the car smoothly both when stopping from full speed and when stopping from creeping speed.

When stopping from full speed the brake should not set until the car has been slowed down to a low speed by electrical braking. When stopping from low speed the brake should set in a very short time after the control handle is thrown to the off position but the torque should build up gradually so as not to produce a jar. The most practical means of controlling the setting of a d-c. brake is to utilize the self induction of the brake coil in such a way that the flux is maintained in the magnet cores and retards or opposes the action of the brake spring in developing braking torque.

With rheostatic control in which the motor armature is disconnected from the line in stopping it is difficult to obtain good brake action and very careful adjustment must be maintained. If the time element of the brake is made long enough to make the action smooth with light loads the slide will be excessive with full load down and loads in the up direction may drop back several inches before the brake can take hold and bring the car to rest. With variable voltage control the armature

circuit is not opened immediately in stopping. When the controller handle is moved to the off position the generator shunt field is disconnected from the line and the generator voltage becomes practically zero. Since the line between the generator and motor armature is not broken, sufficient current will circulate to hold the car firmly under control while the brake sets. The control of the flux in the brake core is obtained with suitable contacts on the control panel and on the brake itself. After the brake has set and the car stopped, the contactor in the armature circuit is opened to eliminate circulating currents that might be produced by residual magnetism of the generator.

Tests were made on a gearless traction elevator rated 2000 lb. at 500 ft. per min., equipped with variable voltage control. The motor generator set consisted of an a-c. driving motor, a variable voltage generator, and a direct-connected exciter. The tests were made with the generator voltage adjusted to give a car speed of 550 ft. per min. with balanced load. The car was started by moving the master controller directly to the full-speed position in starting and stopped by moving directly to the off position. Fig. 4 shows the speed-time curves obtained on these tests. The curves were drawn by a graphic meter which recorded the voltage generated by a magnet driven from the shaft of the elevator motor.

Fig. 4A shows oscillograph records of armature current, generator voltage, and current in the standing field of the motor. The motor also has an extra or starting field which is connected to the line for starting. This increases the total field during the first part of the accelerating period, giving a high starting torque. During the last part of the accelerating period, the generator field is overexcited, in order to maintain a high rate of acceleration. The current in the standing field shows rapid changes in value, but due to its self inductance and to the mutual inductance between this field and the extra starting field the resultant change in flux is small and takes place quite slowly. Fig. 5 shows the currents in the two motor fields and Fig. 5A shows the resultant flux and motor torque. The action of these two fields is discussed more fully later.

The torque developed by the motor is proportional to the product of the armature current times the field flux. As shown by the curves the motor current and torque increase at a uniform rate during the first half of the accelerating period and decrease at a uniform rate during the last half. The rate of change of acceleration is proportional to the rate of change of motor torque and is determined by the tangent or slope of the curve. The speed time curves show that the rate of acceleration increases uniformly as the car starts and reaches a maximum at approximately one half speed. Above half speed the rate of acceleration decreases uniformly as the car comes up to speed. The time required to reach full speed is less than two and one half seconds and is practically the same for all loads.

The retardation curves have the same general characteristics as the acceleration curves. The time required to stop from full speed is very nearly the same for all loads. In practise this uniform retardation under all load conditions makes it possible for car operators to gage the stops very accurately in stopping from high speed and so reduce the number of false stops and time lost in making landings. A dotted portion of the retardation curves is added to show the effect upon retardation of increasing the total field by the addition of the extra field.

Fig. 6 shows the results of tests similar to those shown in Figs. 4 and 5 but made on a gearless traction elevator with rheostatic control. The curve of armature current shows notches as the steps of the starting resistance are short-circuited. These changes in the armature current correspond to changes in motor torque and in the rate of acceleration. The same notches are apparent as the dynamic braking resistance is short-circuited. These rapid changes in the rate of acceleration and retardation make it difficult to obtain smooth

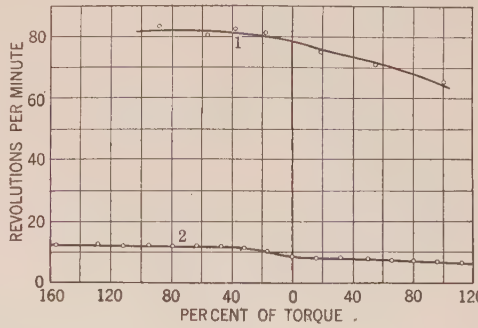

FIG. 7

Speed torque curves of gearless traction elevator motor at full speed and at low speed with variable voltage control.

and comfortable operation. The speed time curves are less uniform than those shown in Fig. 4 and show more variation in time for different loads.

Experience has proved that variable voltage control is smoother in operation than the older system and that passengers can be handled more comfortably and quickly.

An analysis of the test data shows the following reasons for these results:

1. The rate of acceleration increases uniformly as the car comes up to speed and is not subject to rapid changes such as are produced by increasing the armature current in steps.

2. The time required to reach full speed is reduced.

3. The accelerating time and retardation time is constant for all conditions of load.

2. *Regulation and Speed Control.* The speed at which elevator cars can be run depends very largely upon having a system of control that will give a positive low speed for making landings which does not fall off appreciably under load. Fig. 7 shows a test on an

equipment operating on reduced generator voltage. The speed is reduced to 1/10 of full speed at no-load and only falls slightly below this value when hoisting a load. With overhauling load the speed remains low. This flat regulation at speeds as low as 1/10 of full speed makes it possible for the operator to have complete control of the car under all loads.

In elevator work it is entirely practicable to operate the motor over this speed range, or greater, by control of the generator field. Fig. 3 shows the speed at which the generator fields can be changed. The generator field can be varied over such a wide range that very little field control on the motor is necessary. Motor field control,

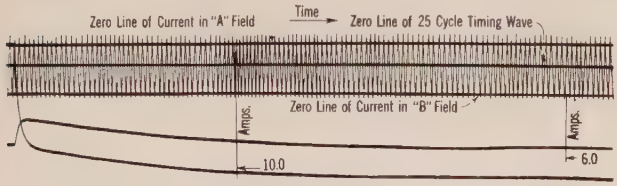

Fig. 8

Oscillograph records showing the rate of change of field currents of a low-speed elevator motor.

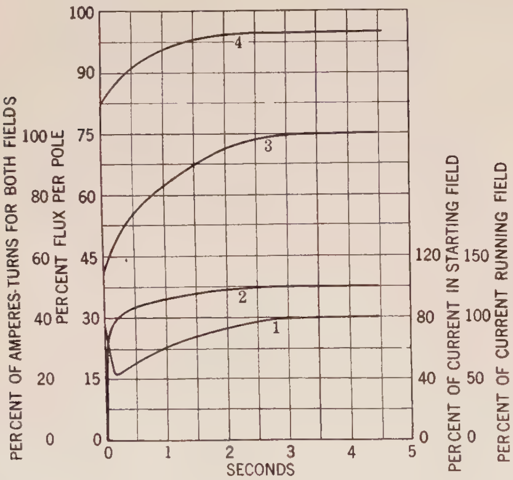

Fig. 9

Curves derived from the oscillograph tests shown in Fig. 8. The curves show the time required to change the motor speed by field control.

if used for any considerable speed range, requires a very large motor. With large low-speed machines it is not practicable to use a very great range of motor field control because of the slowness with which the field flux changes.

Fig. 8 shows oscillograph records of the field control of a gearless traction elevator motor. The motor has two field windings known as the running or *B* field and the starting or *A* field. With both fields energized the motor runs at 50 rev. per min. and with the starting field disconnected at 65 rev. per min. The curves in Fig. 8 shows the current in the running or *B* field with the motor at full speed and the current in the starting or *A* field when it is connected to the line to slow the motor down to 50 rev. per min. The current builds up quite rapidly in the *A* field but the current in the *B* field is reduced by the mutual inductance between the field coils.

Fig. 9 shows derived curves of the combined ampere turns of both field coils and the resultant field flux. Curve No. 4 shows that it requires approximately 3½ seconds for the field flux to reach its final value and

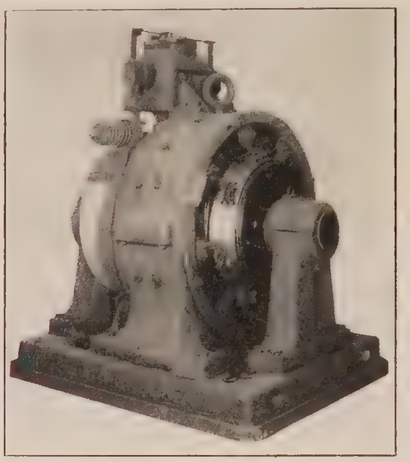

Fig. 10

Photograph of gearless traction elevator motor on which the tests shown in Fig. 8 were taken.

change the motor speed from 65 to 50 rev. per min. In practise an elevator must be retarded and stopped in from 1½ to 2 seconds so it is quite obvious that the full-speed range of this machine cannot be utilized. It is doubtful if a speed range greater than 10 or 15 per cent is practicable for this class of elevator motor. A machine of this type is illustrated in Fig. 10.

Armature series and shunt resistance gives inherently

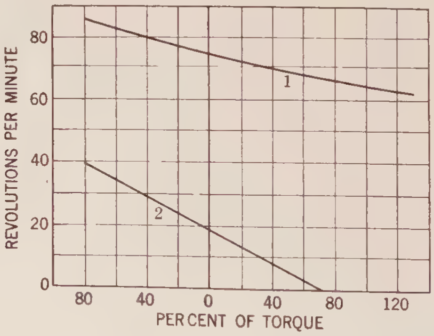

Fig. 11

Speed-torque curves of a gearless traction elevator motor with armature series and shunt resistance. The curves show the difficulty encountered in controlling the speed by this method. The curves in Fig. 7 and Fig. 12 are for the same motor.

poor speed regulation. For gearless traction equipments it has been the practise to use a combination of armature and motor field control. Fig. 11 shows the general shape of speed torque curves of a motor with series and shunt armature resistance. With a motor having the armature resistance shown, when the no-load

speed is reduced to 25 per cent of the full-speed value the motor torque is reduced to 70 per cent at stand still. This means that the motor will not have sufficient torque to hoist full load on this controller point, except by some automatic adjustment of the armature resistance. Considerable complication has been introduced in the control to make it possible to lift full load to the top floor. With overhauling loads it is difficult to make the speed low enough to obtain accurate stops. At best the speed range is quite limited and large currents are drawn from the line when operating on the low-speed points.

The method of speed control by varying the generator voltage shows considerably better speed regulation and a greater range than the other two methods. This is clearly shown by comparing the results shown in Fig. 7 and Fig. 11. In practise this better control results in the following advantages for the variable voltage system.

1. It is much easier for the operator to land accurately at the floors and the number of false stops are reduced.

2. The car may be "inched" to the floor level very accurately and quickly in case the operator does not stop accurately the first time.

3. The limit stops can be made in a minimum distance and without loss of time or over travel with all loads.

4. Elevators may be run at a higher speed than is possible with rheostatic control.

3. *Efficiency and Power Consumption.* The factors that affect the power consumption of an elevator are so many and varied that it is extremely difficult to predict what it will be for a new installation. The more important factors are as follows:

(a) Load and speed.

(b) Number of stops and starts per mile of travel.

(c) The number of miles per hour that the car makes while in service.

(d) The weight of the moving masses that must be accelerated at each start.

(e) Method of operation.

A large number of tests have been made in which the cars are operated on a fixed schedule with different loads and the power consumption measured. These tests are useful in making comparisons between different equipments but do not give accurate information for determining the power consumption in actual service where the cycle of operation may be quite different. Different operators handle the cars in different ways and this will have an effect on the power consumption. In actual operation considerable power and time may be wasted in the following ways:

(a) Acceleration and retardation for every start and stop.

(b) Inching the car to correct for inaccurate stops at the landings.

(c) Running at reduced speed when the cars are ahead of their schedule. (With rheostatic control).

(d) Making the limit stops.

(e) Long idle periods in which the standby loss in the motor field and motor generator sets uses up power. (With variable voltage control).

The power required to drive the elevator at full speed is usually considerably less than that used up in the items enumerated above. The distribution of the power losses will depend very greatly upon the system of control used.

Fig. 12 shows a typical cycle for a high-speed elevator with variable voltage control operating with the average

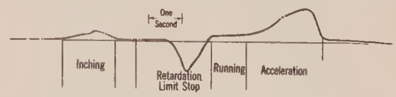

FIG. 12

Power cycle of high-speed elevator with variable voltage control tested with balanced load. The chart was made by a graphic wattmeter.

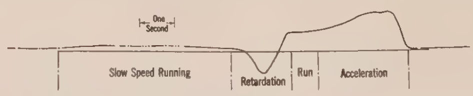

FIG. 13

Power cycle of high-speed elevator with variable voltage control tested with load. The chart was made by a graphic wattmeter.

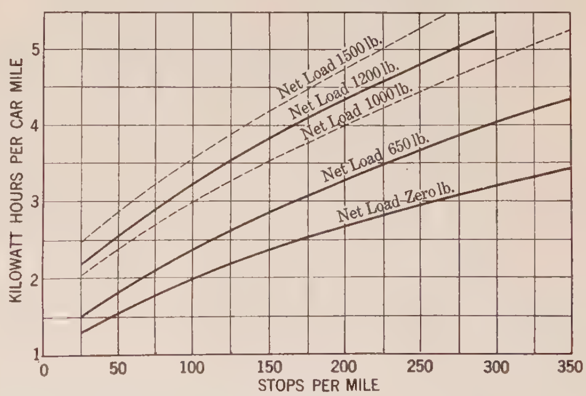

FIG. 14

Energy consumption tests of gearless traction elevator with variable voltage control. Duty 2000 pounds at 500 feet per minute.

or balanced load. The power input is greatest during the accelerating period, and falls off to a very low value as the car comes up to speed. During retardation the power becomes negative and is returned to the line. The effect of inching the car is shown directly following the retarding period. The maximum is only 25 per cent of that required during acceleration. This does not mean that the elevator motor does not develop sufficient torque to move the car promptly. On the contrary the current flowing in the generator and elevator motor circuit is high enough to develop full-load torque or greater but since the generator voltage is quite low the actual power input is also low. Fig. 13 shows a similar cycle but with a loaded car and shows a

period of low-speed running. In this case the power at low speed is 1/3 of that required to run at full speed.

A series of tests were made on a gearless traction elevator having a duty of 2000 pounds at 500 feet per minute and equipped with variable voltage control. Fig. 14 shows the energy consumption in kilowatt hours per car mile plotted against stops per car mile. With balanced car and 125 stops per mile the energy consumption is 2.2 kilowatt hours per mile. The energy consumption shown includes all the power taken from the line.

Fig. 15 shows a test made on an elevator having a capacity of 2500 pounds at 600 feet per minute with rheostatic control. Fig. 16 shows a similar test on the same motor with a smaller sheave and variable voltage control operating at 550 feet per minute. With balanced load and 50 stops per mile the energy consumption is 2.2 kilowatt hours for both equipments. At 150 stops per mile the energy consumption is 3.6 kilowatt hours per mile for the variable voltage equipment and 5.2 kilowatt hours for the rheostatic. While the two

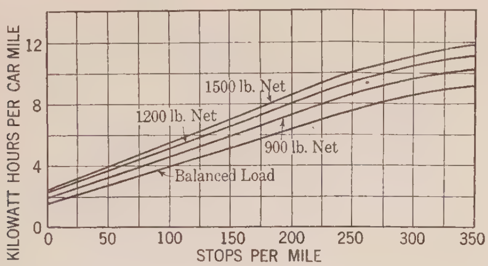

Fig. 15

Energy consumption tests of gearless traction elevator with rheostatic control. Duty 2500 pounds at 600 feet per minute.

motors are not working under exactly the same conditions the slope of the curves gives a fairly good comparison between the two systems of control.

From an analysis of the load curves and the test data we can draw the following conclusions:

1. The variable voltage system requires less power for acceleration and retardation because of the absence of rheostatic losses and because of the power returned to the line during retardation.

2. Very little power is taken from the line to make small movements of the car due to the low generator voltage.

3. Low-speed running does not increase the power consumption.

4. Power is returned to the line while making the limit stops.

5. The greatest gain in economy will be shown where the number of starts and stops is large.

6. Long rest periods will cause waste of power if the motor generator sets are left running. This waste can be eliminated by shutting down the motor generator set through a start and stop push button station which may be located at a point accessible to the starter or mounted in the car.

IV. Safety Features

Elevators have a number of devices which protect the passengers riding in the car. I shall discuss only those that are affected by the control system.

1. *Limit Stops.* An elevator control system should be so designed that the car will be slowed down and finally stopped as it approaches the terminal landings. In order to be sure that the car platform will come flush with the top and bottom landings under all conditions of load, the stop contact on the slow-down device must not open until the car has reached the floor level. It is preferable that the point of cut-off be a few inches beyond the floor level so that the operator will not form the habit of depending entirely upon the automatic device for making the stop. It is necessary then, when the car reaches the cut-off point, that it be slowed down to a low enough speed so as not to drift further than the distance provided for over travel. If the car runs by the over-travel limit switch it is not possible, with the usual connections, to back out and the assistance of an attendant is necessary to put the car into service again. To stop a fully loaded car within the usual over-travel distance has always been a considerable problem with rheostatic control because of the extremely poor regulation of the motor when operating at reduced speed with armature series and shunt resistance. The characteristics of the machine operating under these conditions have already been discussed. Refer to Fig. 11.

A switch is mounted on the car having contacts actuated by an arm and roller which engages a cam in the elevator shaft. As the car approaches the top and bottom landings these contacts operate to insert steps of resistance in the generator field, in the variable voltage system, which reduces the voltage. The car speed reduces with the reduction of voltage due to the regenerative braking that takes place until, as the landing is approached, the car is running at very low speed.

The inherent regulation of the variable voltage system makes it possible to slow down a fully loaded car in almost the same distance as an empty car. It is possible to stop the car at the terminal landings under all conditions of load within one inch of the same spot. The positive action of the automatic slowdown at the limits of travel greatly increases the safety of operation. The automatic slowdown and stop at the terminal landings is one of the elements in the system of safety devices provided for the elevator and it is important that it function properly.

2. *Emergency Stop.* When making normal stops with the regular controlling means such as the car master switch or the automatic limit stops, the generator field is reduced to zero which sets up regenerative braking in the elevator motor which slows it down. At the same time the friction brake sets which brings the car to rest. To provide against failure of the master switch contacts to function or a failure of the regular stopping cycle the car is equipped with the usual

emergency switch. This switch opens the armature circuit contactor which disconnects the elevator motor entirely from the generator and connects it to a low-resistance dynamic braking circuit. The coils to the brake contactors are opened and the brake circuit itself is also opened by auxiliary contacts on the armature contactor. This arrangement gives two entirely independent means of stopping the car and is an advantage over the older forms of control in which the emergency switch forms only an additional means of opening the same contactors that disconnect the motor in regular operation.

3. *Failure of Power.* The failure of the main power supply on a large system is a comparatively rare occurrence, but failure of power from some cause to elevator motors has been a rather frequent source of trouble. Failure of power to an elevator may be due to (1) failure of the main power supply to the building, (2) the opening of the main circuit breaker in the building, (3) opening of the circuit breaker or blowing a fuse in the line feeding the elevator. I shall analyze the result of a power failure under several conditions and discuss means for taking care of the condition.

When the motor is operating under positive load, that is when hoisting an unbalanced load, there is no particular danger from power failure as the car will stop of its own accord in a comparatively short distance. The condition of balanced or overhauling load presents a more serious problem. Let us consider first the case of overhauling load produced by a fully loaded car going down. Consider first the case of a d-c. motor controlled by armature series and shunt resistance and motor field control. With overhauling load the motor is operating as a generator and returning power to the line and is kept at constant speed by the supply voltage. The contactor magnets on the controller are energized from the supply voltage. If now the power source is cut off by an opening of the circuit breaker in the line to the motor, the reservoir into which the motor has been delivering its power will have been disconnected and the motor and car will overspeed. There will be no warning to the operator that the power has failed until the car has reached a considerable overspeed, probably high enough to trip the safety clamps under the car. The control magnets will be kept energized by the voltage generated in the armature of the elevator motor so that the dynamic braking circuits will not be set up or the friction brake disconnected until the overspeed governor driven by the car has opened its contacts. In other words, there is nothing to start the functioning of the control to stop the car until there has been an actual overspeeding of the car. After the control has functioned to stop the car the friction brake will be called upon to make most of the stop since the electrical braking will be rendered more or less ineffective due to the dying field of the elevator motor. Control schemes have been developed to connect the field of the motor to the armature so as to maintain the excitation. In some cases the motors have been equipped with special fields for this purpose. Such schemes are only partially successful and the principal difficulty is to initiate the functioning of the control before the car has reached considerable overspeed. In special cases the control circuits have been connected through auxiliary contacts on the circuit breaker.

Alternating-current squirrel-cage elevator motors that use a separate winding which must be excited from the supply line have no means of obtaining regenerative braking when power fails and the friction brake alone must stop the car.

Consider next the case of an elevator motor driven through an motor generator set with an a-c. driving motor and having either one or two generators. The motor generator set comprises a small direct-connected, self-excited generator to furnish d-c. excitation to the generator and motor fields, brake and control circuits. In case of overhauling load the elevator motor is acting as a generator, the generator end of the motor generator set is acting as a motor, the motor of the set acts as

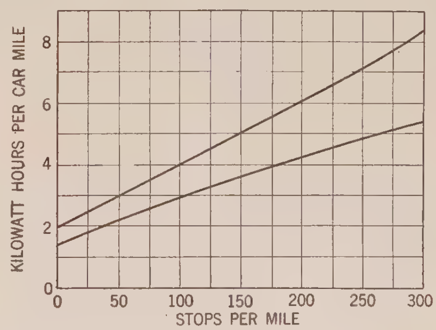

Fig. 16

Energy consumption tests of gearless traction elevator with rheostatic control. Duty 2500 pounds at 550 feet per minute.

an induction generator and is running above synchronous speed. It should be kept in mind that the elevator motor is generating a voltage higher than its terminal voltage due to the drop in the windings. For the same reason the generator, acting now as a motor, is generating a counter voltage lower than its terminal voltage by the value of its internal drops.

When the circuit breaker opens the energy that is being developed by the descending car is expended in accelerating the motor generator set which speeds up until the generator voltage equals the voltage generated by the elevator motor, the internal drops reducing to a very low value. The result will be an overspeed on the set of 15 or 20 per cent above synchronous speed. The motor generator set is equipped with an overspeed device which opens a contact in the safety circuit of the elevator controller that sets the friction brake and sets up the emergency dynamic braking circuit. The motor generator set is now running free at overspeed and due to its inertia runs for several seconds before the direct-connected exciter

loses its voltage. The field of the elevator motor is connected directly to the exciter so that a strong field is maintained for dynamic braking long enough to bring the car completely to rest before the exciter loses its voltage. The same cycle is performed when the driving motor of the set is a d-c. machine. The only difference is in the connections of the field of the elevator motor which are such that the counter e. m. f. of the driving motor maintains the excitation on the elevator motor field. Tests have shown that the car is stopped promptly and without over travel when a power failure occurs while making the limit stops.

4. *Overspeed.* The cars are equipped with the usual overspeed governor which performs the usual functions of first slowing down the car by field control, opening the safety circuit and finally setting the wedge clamp safety under the car. The overspeed contact on the motor generator set acts as an additional factor of safety as it opens the safety circuit independently of the speed governor. It can be set to open its contacts before the governor trips and so stop the car entirely by means of the electrical and friction brakes, saving the inconvenience and loss of time in releasing the wedge clamp and resetting the governor before the car can be moved to the nearest landing.

IV. Maintenance

The upkeep of equipment is one of the factors that go to make up the cost of operating electric elevators. Large buildings usually employ someone who is competent to care for and maintain the elevator equipments. Such buildings usually have excellent elevator service and experience little trouble from shutdowns and delays. At the other extreme we find buildings in which no regular help is employed for this purpose and elevator maintenance consists of periodic inspection for which service contracts are often let.

Maintenance of the electrical equipment consists mainly of inspection, cleaning, making adjustments, oiling and installing renewal parts. The first three items involve labor costs only, while the last two items involve both labor and material. It should be the desire of every building owner to purchase equipment on which he can reduce the last three of these items to a minimum.

The art of designing rotating machinery has advanced to a point where maintenance is merely a matter of routine. Elevator machinery is usually installed in comparatively clean places so that insulation trouble is comparatively rare. The elevator cycle is such that machines which are designed to have the proper operating characteristics seldom reach, in actual service, the maximum temperature rise which they are guaranteed to stand. The use of commutating poles has made it possible to design high-speed d-c. machines that will commutate heavy-current peaks with practically no sparking. The present accepted standard of commutation is that the commutators shall improve their appearance, in actual operation. Bearings, oiling systems and general mechanical design have been developed to a high degree of perfection.

Elevator controllers have in recent years reached a high state of development but there is one inherent condition that has made the maintenance problem more difficult. I refer now to the rupturing of heavy currents in starting and stopping the motor and in performing other control functions such as changing speeds. A contactor in elevator service is rupturing heavy currents continuously and the arc produced when the circuit is opened is bound to burn away the contacts. Considerable improvement has been made in recent years in the method of rupturing arcs, such as the use of arc splitters, and improvements in the design of the magnetic blowout. The use of rolling contacts has considerably improved the life of the contacts themselves.

It is quite probable that these details are now pretty well standardized and that little improvement can be expected along this line. The next step is to eliminate the rupturing of major currents altogether and to control them indirectly. This is accomplished by switching only the field current of the generator, which, as its voltage changes, controls the elevator motor. The equipment can be so designed that the maximum current ruptured by the controller is not more than five amperes. From the standpoint of maintenance this results not only in an increased life of the contacts themselves but in reduced cost of renewal parts, since the contactors are much smaller in size than if they had to handle the motor current directly. The elimination of heavy arcs reduces the burning of other parts and the chances of damaging flashovers. The acceleration and retardation is governed by the characteristics of the generator field and does not depend to a great extent on adjustment of relays and contactors so that the controller requires very little attention to keep it in good operating condition.

Another item that has an effect upon the maintenance of elevators is the wear and tear on machinery incidental to severe service. The life of the cables and the wear on gears are both affected by the control equipment. High-speed geared elevators develop backlash in the gears and this is aggravated by the notching of the ordinary controller. Sharp peaks in the retardation torque have a tendency to cause slippage of the cables and reduce their life. Fig. 5 shows the smoothness of acceleration and retardation and the absence of abrupt changes in motor torque. This smoothness will result in longer life and less maintenance cost of the mechanical equipment.

V. Conclusion

In the foregoing part of this paper I have attempted to describe the variable voltage system of control as applied to electric elevators and to set forth the characteristics and operation obtained. In conclusion

I shall summarize its principal advantages for elevator work as compared with older systems.

1. Elevators running at the highest speeds may be driven from a-c. supply lines of any commercial voltage and frequency.

2. The acceleration and retardation are perfectly smooth and uniform.

3. A high rate of acceleration and retardation is obtained which permits the use of high car speeds and increased elevator capacities.

4. Positive speed control under all conditions of load makes it easy for operators to land the car accurately without loss of time.

5. High economy of power is obtained.

6. A number of inherent safety features make it particularly suitable for high car speeds.

7. Maintenance costs are reduced to a minimum and the reliability of service increased because of the simplicity and flexibility of the system and because no large currents are ruptured in operation.

Appendix

Symbols used in equation (**1**).

M_1 = Moment of car counter weights and other moving parts.

M_2 = Moment of motor armature.

V = Velocity of the car.

T_B = Torque developed by the friction brake.

T_L = Torque developed by the load.

K_1, K_2 = Constant.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

A YEAR'S PROGRESS IN ILLUMINATION

A Brief Resumé of the Report of the Illuminating Engineering Society's Committee on Progress

The annual report of the Illuminating Engineering Society's Committee on Progress, reviews the year's advances as chronicled in the various periodicals, excepting those already reported in the Transactions of that Society. The current report, presented at the Lake George Convention, and published in the I. E. S. Transactions for September 1923, occupies 92 printed pages. Even eliminating those portions which are of interest to lighting specialists, the report is so extensive that only a few of the important topics can be briefly touched upon here.

Experiments and investigations on the effect of increased illumination on production in various industria processes are beginning to show results in quite a general tendency toward higher illumination levels in recent installations. The Post Office Department has indicated its appreciation of the importance of better lighting by the extended study of lighting conditions in post offices. The duration and apparent thoroughness of their tests give considerable weight to their conclusions and recommendations, which may be found applicable in other lines of business.

Considerable progress has been made toward fuller cooperation of the engineering and artistic groups, especially architects and the luminaire industry, the benefits of which are obvious.

Incandescent Electric Lamps are extensively treated under a number of subheads. A tabulation shows the number of incandescent lamps consumed annually per capita to be—United States 1.83; Switzerland 1.62; Germany 0.88; France 0.72; Austria 0.67; England 0.45; Italy 0.38; Hungary 0.37.

Of the incandescent lamps sold in the United States in 1922, only 1.5 per cent in number were carbon. Of the tungsten filament lamps, 79.5 per cent in number were vacuum type and 20.5 per cent gas-filled. The average efficiency was 11.5 lumens per watt. The most popular sizes were the 40, 25 and 50 watt vacuum lamps and the 75 and 100 watt gas-filled lamps.

The 115-volt class includes 88.2 per cent of the total, of which 115, 110 and 120 volts were strongly predominant. These comparisons refer to the so-called large lamps. The growing importance of the miniature tungsten lamps, with which the automobile types are included, is indicated by the fact that numerically, they form 29 per cent of the grand total.

Mention is made of the international conference for the standardization of lamp bases throughout the world.

The "mill" lamp with concentrated filament is now of especially sturdy construction and is being used also for sign lighting. Both colorless and blue glass bulbs are being used.

The extensive investigation of arc and vapor tube lamps, promises much for the future, but nothing new for immediate practical application appears to be reported.

In the field of automobile lighting, mention is made of a new courtesy lamp and various headlight developments. Investigations of tail lights with reference to the illumination of number plates, have been carried on. It should be mentioned that a recent standardization has resulted in the redesign of rear lanterns, so that with new equipment, license plates can be effectively illuminated.

Railway signalling with electric lamps has extended rapidly in application. Among the new features, is the "sun-valve" (or switch.)

For motion picture projection, mention is made of a new arc lamp in which a reflector is used instead of a condensing lens.

Under Street Lighting, attention is called to the reports of the National Electric Light Association's Lighting Sales Bureau and the American Society for Municipal Improvements Committee. The latter makes tabular recommendations for sizes, heights and spacings of street lighting units.

New York City had at the close of 1922—81,731 street lamps, of which 73,930 were electric.

The cluster type of street lighting units are giving

way to the single light types more rapidly with the availability of large size incandescent lamps. This is resulting in a better architectural appearance of the streets. There is a strong trend toward the urn shaped globes in preference to the spherical. Experiments are being made with equipment giving a symmetrical distribution of light.

Sign lighting is also showing rapid progress. Statistics from 8 cities, ranging from 10,000 to 350,000 population show one sign and 202 sockets for every 75 persons. What is claimed to be the largest electric sign in the world, is 153 ft. long, 75 ft. high. It is legible from a distance of 8 miles and visible from 30 miles.

Aerial navigation is making demands for new forms of lighting equipment. The aerial lighthouse at College Point, Long Island, is said to be the first in this country. It employs a 14-in. navy searchlight. Night mail service requires landing field lighting and lines of beacons across the country.

New Bridge Lighting installations are reported, *viz.* Springfield, Mass. and Schenectady, N. Y. A notable temporary illumination was provided at the opening of a bridge at Little Rock, Ark.

The recent advances in practise have been so great that the redecoration of any public building is not complete without a revision of the lighting system.

For a recent prize fight, an illumination of 45-foot candles was provided and directed in such a way as to avoid glare in the eyes of the spectators.

One of the serious problems of art galleries, is to avoid fading of exhibits. A recent study showed that direct sunlight is most destructive, and that artificial light is much less likely to produce fading than diffused daylight. It was concluded that materials having fugitive colors should be exhibited only in artificial light. Some of the recently built galleries employ new methods of lighting.

A brief description of the lighting of the Steamship Leviathan indicates the liberal use of decorative lighting—150,000 lamps being employed.

At the American Railway Association's convention, the Committee on Locomotive and Car Lighting made recommendations for the equipment to be standardized for various applications on trains.

A store lighting survey recently conducted in a middle western city, showed that only 25 per cent of the stores had five or more foot candles, and that only 2 per cent had levels as high as 10 foot candles. Since that time the illumination in several classes of stores has been approximately doubled. An eastern store provides special window lighting equipment by means of which the lighting effect is changed for every night in the year.

In a textile spindle shop with directed artificial light, the production has been increased 25 per cent over that obtained in daylight.

An important new industrial lighting unit has been produced through cooperation of reflector manufacturers, glass makers and illuminating engineers. This consists of an enameled steel reflector and glass diffusing globe. Openings in the steel reflector permit about 7 per cent of the light to reach the ceiling, thus avoiding harsh contrasts. The equipment is made in two sizes—one with 18 inch diameter of reflector for 100 to 200-watt lamps, and the other with 20-inch reflector for the 300 to 500-watt lamp. The efficiency of the equipment is 65 per cent and the brightness 2 to 5 candle power per square inch.

Industrial reflectors, both bowl and shallow dome type, have been adopted for use with the "multiple" incandescent lamps. Other improvements of industrial equipment are recorded. Several new and improved luminaires for other classes of service are referred to, including an enclosed unit for kitchen lighting, hospital units and portables. Among accessories reported are impregnated silk shades, device for converting direct lighting unit to indirect, switch plate, screwless shade holder, wired tubing and automatic time switch.

Investigations concerning loss of light from dirty equipment, led to a classification of dirts, with varying losses. Cleaning increased light output by percentages as high as 77 and 84. It is pointed out that windows and skylights require cleaning fully as much as lamp equipment. Tests on samples taken from shops showed increases of from 4 to 15 times in light transmission, due to cleaning.

Tests of street lighting globes in a northern city showed that, when not ventilated, their surface permitted sufficient radiation to avoid harmful temperature while the accumulation of dirt and moisture within the globes was prevented.

Under Photometry, Units and Instruments, reference is made to considerable research in foreign countries. In reference to hecterochromatic photometry, considerable comparative data have been secured regarding the flicker and equality of brightness methods. Further data have been secured on the necessity of various light sources, and also regarding luminescence and phosphorscence. Photo-electricity and the advances in photoelectric cells are rather extensively discussed.

In photography, luminous intensity from an electrically exploded wire promises to give aid for instantaneous exposures.

The application of artificial light to plant growth is not only giving promise of some new practical uses, but also revealing new information regarding the nature of such growth, flowering, seeding, etc.

It is recorded that the largest telescope in the world, *viz.*: the 100-inch reflector at Mount Wilson Observatory, collects 160,000 times the light received by the naked eye.

The report is concluded with a list of books issued during the year, numbering eighteen.

Foot note references to sources of information are given, of which eight are to the JOURNAL of the American Institute of Electrical Engineers.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Interesting Program for Midwinter Convention

Interest is continuing to grow in the coming Midwinter Convention which will be held in Philadelphia, February 4 to 8. The special features of the convention which will attract wide attention are a series of talks by railroad officials and other prominent men, the celebration of the fortieth anniversary of the Institute, the presentation of the Edison Medal and the dedication of the Moore School of Electrical Engineering. In the technical program there are included papers on transmission, measuring instruments, electrical machinery, elevators, telephony electrophysics and a number of other engineering subjects. Philadelphia is a city of unusual historic interest and visits to places famed in history as well as those which hold engineering interest will add to the pleasure of the meeting. Other enjoyable entertainment features also are being arranged.

Presentation of Edison Medal

This year the Edison Medal will be presented to John W. Lieb, Vice-President, New York Edison Company, on the evening of Monday, February 4. Mr. Lieb is the fourteenth man to receive the medal which is awarded for meritorious achievement in electrical science, electrical engineering or the electrical arts.

Celebration of 40th Anniversary

As the year 1924 is the fortieth since the founding of the Institute, this convention has been chosen as a fitting occasion for celebrating the anniversary. Three of the founders of the Institute, T. C. Martin, J. Elmer Sperry and Elihu Thomson will tell of the first years of the organization, pointing out as well the status of electrical engineering in the early days and the developments which have come since that time. John C. Carty will talk on the evolution of the Institute and its present functions and accomplishments. This meeting will be held on the evening of Monday, February 4.

Railroad Sessions

In the sessions devoted to railroads an allied industry will have the opportunity to discuss its problems under the auspices

PHILADELPHIA PARKWAY AND APPROACH TO FAIRMOUNT PARK, BELL TELEPHONE COMPANY'S EXECUTIVE OFFICES IN FOREGROUND. PHOTOGRAPH TAKEN FROM CITY HALL. FAIRMOUNT PARK IN THE DISTANCE

of the Institute. The engineering and economic aspects of transportation will be treated by officials of the railroads and other high authorities. At an afternoon meeting on February 5 at the Bellevue-Stratford Hotel, the operating phase will be covered by speakers who will talk on such subjects as train tonnages, locomotive performance, train movements, terminal movements, train speeds and acceleration rates. They will also enumerate the future requirements of transportation.

INDEPENDENCE HALL

At the evening meeting in the Metropolitan Opera House general transportation topics will be discussed by national authorities. Among the speakers are President Maher of the Norfolk and Western; President Budd of the Great Northern Railway; President Markham of the Illinois Central and Vice-President Buckland of the New York, New Haven and Hartford. Prospects are bright for having Secretary Hoover and President Smith of the New York Central as speakers. Arrangements

Delaware Station of the Pennsylvania Electric Company showing Penn Treaty Park where William Penn under the great elm, which blew down in 1910, signed treaty with Indians in 1682.

are under way to broadcast this meeting from New York, Washington and Providence through cooperation of the American Telephone and Telegraph Company, from Philadelphia through a local station, from Schenectady through the General Electric Company and possibly from Pittsburgh and Hastings, Nebraska, through the Westinghouse Electric & Manufacturing Company. Railroad officials are working with the Institute to make this a meeting of national importance.

Dedication of New Moore School

The new Moore School is the first School of Electrical Engineering to be endowed as such. This school which will form part of the University of Pennsylvania will be dedicated by the Institute on Wednesday afternoon, February 6. The University authorities in arranging for the ceremony have planned for an interesting and profitable visit for the Institute members as guests of the University.

Entertainment Plans

On Wednesday evening an informal smoker, dance and entertainment will be furnished and on Thursday evening the annual dinner will be held at the Bellevue-Stratford. A number of trips to places of interest have been arranged. Special arrangements have been made for the ladies, in order to make their visit to Philadelphia most pleasant.

The Lehigh Valley Section has arranged for an enjoyable afternoon and evening on Friday. In the afternoon there will be a visit to the plant of the Bethlehem Steel Company, one of the largest plants in the country, and in the evening the visitors will be the guests at an entertainment and meeting.

Technical Program

Many interesting and valuable papers will be presented at the technical sessions. Several interesting papers will be given on electrical machinery and three papers on the latest developments in elevator control and design will be read.

Superpower transmission will be covered in a notable group of papers which contain advanced knowledge on the stabilization and other characteristics of transmission systems.

In research and electrophysics there are papers dealing with insulation, dielectrics, ionization and magnetization.

New kilovolt-ampere meters and a novel high-resistance voltmeter will be treated and there will be several interesting papers on radio, telephony and telegraphy.

Headquarters will be at the Bellevue-Stratford Hotel. Requests for reservations should be sent directly to the hotel management. All plans are being perfected by the local committee to make the convention a very enjoyable and profitable one.

Transportation Rates

Application has been made for reduced rates on the certificate plan, which requires each person to purchase a one-way ticket and to obtain from the selling agent a certificate, which upon presentation at the convention will entitle the passenger to one-half rate for the return trip by the same route, *provided at least two hundred fifty of the certificates are presented at the convention.* Members should advise their local ticket office when purchasing their tickets of their intention to attend the A. I. E. E. convention, and should ask for the certificate.

TECHNICAL PROGRAM

Monday, February 4

Morning

Registration and committee meetings

Afternoon

Technical Session

Economics and Limitations of the Super Transmission System, by Percy H. Thomas, Consulting Engineer, New York, N.Y.

Some Theoretical Considerations of Power Transmission, by C. L. Fortescue and C. F. Wagner, both of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Power Transmission, by F. C. Hanker, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Power Limitations of Transmission Systems, by R. D. Evans and H. K. Sels, both of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Experimental Analysis of the Stability and Power Limitations of Transmission Systems, by R. D. Evans, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., and R. C. Bergvall.

Limitations of Output of a Power System Involving Long Transmission Lines, by E. B. Shand, Design Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Evening

Celebration of the 40th Anniversary of the Institute. Speakers: T. Commerford Martin, Elihu Thomson, Elmer Sperry and J. J. Carty.

Presentation of Edison Medal to John W. Lieb, Vice-President, New York Edison Co.

TUESDAY, FEBRUARY 5

MORNING—TECHNICAL SESSION

Gaseous Ionization in Built-Up Insulation-II, by J. B. Whitehead, Dean, School of Engineering, Johns Hopkins University, Baltimore, Md.

Overdamped Condenser Oscillations, by Charles P. Steinmetz,* Chief Consulting Engineer, General Electric Co., Schenectady, N. Y.

Free Convection of Heat in Gases and Liquids-II, by C. W. Rice, General Electric Co., Schenectady, N. Y.

The Magnetic Properties of the Ternary System Fe-Si-C, by T. D. Yensen, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Alkali Vapor Detector Tubes, by H. A. Brown and C. T. Knipp, both of the University of Illinois, Urbana, Ill.

AFTERNOON AND EVENING

Operating Aspects of Railroad Transportation and Transportation Meeting at Metropolitan Opera House, addresses by Ralph Budd, President, Great Northern Railway Co., N. D.

UNITED GAS IMPROVEMENT BUILDING

Maher, President, Norfolk and Western Railway; C. H. Markham, President, Illinois Central Railroad; Edw. G. Buckland, Vice-President, N. Y., N. H. & H. R. R.; L. G. Coleman, Asst. General Manager, Boston & Maine Ry. (Other speakers to be announced later.)

WEDNESDAY, FEBRUARY 6

MORNING—TECHNICAL SESSION (A)

Transient Performance of Electric Elevators, by David Lindquist, Otis Elevator Co., New York, N. Y., and E. W. Yearsley, Electrical Engineer, Brooklyn, N. Y.

Variable Voltage Control Systems as Applied to Elevators, by E. M. Bouton, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

A Novel Alternating-Current Voltmeter, by L. T. Wilson, American Telephone & Telegraph Co., New York, N. Y.

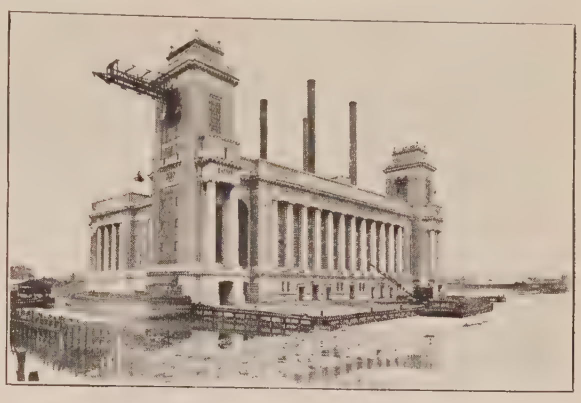
Oscillographic Study of Voltage and Current in Permeameter Circuit, by W. B. Kouwenhoven, Dept., of Electrical Engineering, Johns Hopkins University, Baltimore, Md., and T. L. Berry, Jr.

*Deceased

Power Plant Auxiliaries and Their Relation to Heat Balance, by A. L. Penniman, Jr., Consolidated Gas, Electric Light & Power Co., Baltimore, Md.

MORNING—TECHNICAL SESSION (B)

Shaft Currents in Electric Machines, by P. L. Alger, General Electric Company, Schenectady, N. Y., and H. W. Samson.

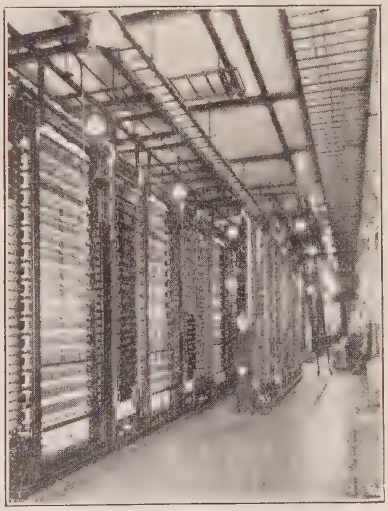


CHESTER STATION, PHILADELPHIA ELECTRIC CO.

Eddy Current Losses in Armature Conductors, by R. E. Gilman, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Tooth Pulsations in Rotating Machines, by T. Spooner, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Surface Iron Losses with Reference to Laminated Materials, by T. Spooner, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., and I. F. Kinnard, General Electric Co., Lynn, Mass.



PART OF THE APPARATUS IN THE "SHERWOOD" OFFICE OF THE BELL TELEPHONE COMPANY OF PENNSYLVANIA, AT 57TH AND CHESTNUT STS., PHILADELPHIA, PA. THIS WAS THE FIRST BELL MACHINE SWITCHING OFFICE TO BE PUT IN SERVICE IN PENNSYLVANIA

AFTERNOON

Dedication of the Moore School of Electrical Engineering at the University of Pennsylvania

EVENING

Illustrated Lecture on 220,000-Volt Transmission, by Frank G. Baum, Consulting Hydroelectric Engineer, San Francisco, Cal.

Entertainment and Dance.

THURSDAY, FEBRUARY 7

MORNING—TECHNICAL SESSION (A)

Method of Testing Current Transformers, by F. B. Silsbee, Physicist, Bureau of Standards, Washington, D. C.

Recent Developments in Kilovolt-Ampere Metering, by B. H. Smith, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. and A. R. Rutter.

Automatic Transmission of Power Readings, by B. H. Smith, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., and R. T. Pierce.

Quadrant Electrometer for Measurement of Dielectric Loss, by D. M. Simons and W. S. Brown, both of the Standard Underground Cable Co., Pittsburgh, Pa.

CHRISTIAN ST. SUBSTATION, PHILADELPHIA, PA.

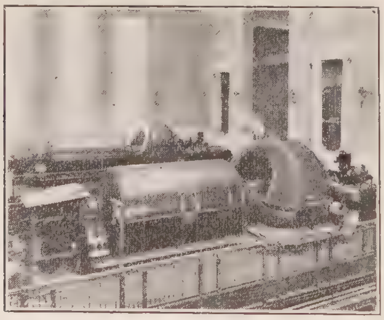
MORNING—TECHNICAL SESSION (B)

Recent Advances in the Manufacture and Testing Static Condensers in Power Sizes, by R. Marbury, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Effect of Time and Frequency on Insulation Tests of Transformers, by V. M. Montsinger, General Electric Company, Pittsfield, Mass.

Insulation Tests of Transformers as influenced by Time and Frequency, by F. J. Vogel, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Short Circuits of Alternating-Current Generators, by C. M. Laffoon, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.



CHESTER STATION UNIT

AFTERNOON—TECHNICAL SESSION

Economic Development of Step-by-Step Automtic Telephone Equipment, by P. G. Andres, Automatic Electric Co., Chicago, Ill.

High Quality Transmission and Reproduction of Speech and Music, by W. H. Martin, American Tel. & Tel. Co., New York, N.Y., and H. Fletcher, Western Electric Co., New York, N. Y.

Function and Design of Horns for Loud Speakers, by C. R. Hanna, and Joseph Slepian, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Certain Features Affecting Telegraph Speed, by H. Nyquist, American Tel. & Tel. Co., New York, N. Y.

EVENING

Annual Dinner Dance

FRIDAY FEBRUARY 8, 1923

MORNING—TECHNICAL SESSION (A)

Measuring Methods for Maintaining the Transmission Efficiency of Telephone Circuits, by F. H. Best, American Tel. & Tel. Co., New York, N. Y.

Low Frequency Signaling System by C. S. Demarest, American Tel. & Tel. Co., New York, Milton L. Almquist, American Tel. & Tel. Co., and Lewis M. Clement.

Telephone Transformers, by W. L. Casper, Western Electric Co., Inc., New York, N. Y.

An Electrical Frequency Analyzer, by R. L. Wegel, and C. R. Moore, both of the Western Electric Co., New York, N. Y.

MORNING—TECHNICAL SESSION (B)

Multiple System of Cooling Large Turbo-Generators, by Donald Bratt, Brooklyn Edison Co., Brooklyn, N. Y.

An Experimental Study of Ventilation of Turbo-Alternators, by C. J. Fechheimer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Importance of Brush Mounting, by P. C. Jones, Goodyear Tire and Rubber Co., Akron, Ohio.

Theory of Three-Circuit Transformers, by A. Boyajian, General Electric Co., Pittsfield, Mass.

AFTERNOON

Visit to Bethlehem Steel Company.

EVENING

Entertainment and visit as guests of Lehigh Valley Section at Lehigh University.

MIDWINTER CONVENTION COMMITTEES

The personnel of the Midwinter Convention Committee is as follows: W. C. L. Eglin, Chairman, L. F. Deming, I. C. Forshee, G. A. Harvey, W. F. James, L. C. Lynch, Ross B. Mateer, William McClellan, L. W. W. Morrow, Harold Pender, Paul Spencer.

At a meeting of the general committee held on November 21st, chairmen of several subcommittees were appointed as follows: Finance, F. J. Chesterman; Entertainment, J. C. Lynch, Registration, W. F. James; Inspection Trips, Paul Spencer; Publicity, L. F. Deming; Dedication of Moore School, Harold Pender; Transportation, I. C. Forshee.

POINTS OF INTEREST AROUND PHILADELPHIA

Philadelphia is particularly rich in objects of historical interest dating from William Penn's time in the 17th Century. Most famous of course is Independence Hall, which holds the Liberty Bell and in which the Declaration of Independence was signed. Next in fame probably is Valley Forge which is nineteen miles out of Philadelphia and is preserved as a state reservation. There are numerous other historically interesting landmarks, many of which are included in the following list.

Independence Hall

Begun in 1732 and completed in 1741. In this building the Declaration of Independence was signed and the Constitution was framed and adopted; Washington was appointed Commander-in-Chief of the American forces and the Continental Congress met from 1775 till the close of the Revolution. The Liberty Bell and many other relics repose here.

Betsy Ross House

Where Betsy Ross sewed the first flag of the Stars and Stripes under Washington's direction.

Congress Hall

Temporary capital of the Nation where Washington (for second term) and John Adams were inaguurated and Thomas Jefferson presided over the U. S. Senate.

Valley Forge

Chief objects of interest are Washington's headquarters (1777-1778), Washington Inn, Wayne Monument National Arch and

the Memorial Chapel. This is a 450-acre state reservation nineteen miles from Philadelphia and is reached by the Philadelphia and Reading Railroad or by automobile.

Carpenter's Hall

Where the first Continental Congress met.

Old City Hall

Where the first Supreme Court of the United States met.

Penn Treaty Tree

In 1682 William Penn concluded his treaty with the Indians on this site.

Franklin's Grave

In Christ Church burial ground.

Gloria Dei (Old Swedish) Church

Oldest structure in Philadelphia.

Christ Church

Built in 1731 and is the church in which Franklin and Washington worshipped and where Robert Morris, Francis Hopkinson and other Colonial figures are buried.

First Presbyterian Church

Had the first Presbyterian congregation in American.

University of Pennsylvania

Founded in 1740. It has now 75 buildings on 117 acres of campus, enrolling 15,000 students.

Old Markets

Several survivors of old street markets.

America's Oldest Bank Building

Now occupied by Girard National Bank.

Among the modern places of interest are the following:

United States Mint

Where two-thirds of the coinage of the country is made.

Navy Yard

League Island Navy Yard, four miles from City Hall, is one of the largest in the country.

City Hall

A fine view of the city may be had from the 548-ft. tower. The structure cost $25,000,000.

The Parkway

This thoroughfare, partly completed, will be the site of an art museum, a public library and other large buildings.

Bell Parkway Building

One of the most modern and complete telephone buildings in the world.

Curtis Publishing Company

Largest housed publishing plant in the world occupying one square block.

Baldwin Locomotive Works

Largest locomotive works in the world, covering nine city blocks.

Of interest particularly to engineers are the following:

Franklin Institute

Where many of the earliest researches and experiments in the science of electricity were carried out. The Institute includes a museum where very old types of electrical equipment are on display.

Philadelphia Electric Company

Chester Station is of special interest as it has two 33,333-kv-a. generating units installed with provision for two more of the same rating in 1924. Delaware Station and other plants are also of interest.

United Gas Improvement Company

This company controls electrical subsidiaries in Norristown and Ardmore, Pa., and elsewhere.

Bell Telephone Company

Has one of the most modern machine switching exchanges and manual exchanges.

Other Electrical Power Companies

Spring Convention Plans Being Perfected

Many interesting features are being planned for the Spring Convention which will be held in Birmingham, Alabama, April 7th-11th. The program which has been proposed should attract electrical engineers from all sections of the country.

Among the topics which will be discussed are oil circuit breakers, high-tension transmission lines and equipment, operation of interconnected systems, lightning arresters, relaying systems, hydroelectric development and equipment, electric furnace regulation, carrier-wave communication, and other subjects. The practises of the different parts of the country will be treated by men from various localities and it is thought that very valuable discussions will result.

As a special feature a meeting is planned to treat of the electrical development of the South—Its meaning to the South and the Nation. Utility executives, industrial leaders and other high authorities will speak on the various phases of this subject. Among those who have already accepted invitations to speak are O. C. Merrill, Executive Secretary, Federal Power Commission; T. W. Martin, President, Alabama Power Company; Preston Arkwright, President, Georgia Railway & Power Company, and H. M. Addinsell, Harris, Forbes and Company.

The papers scheduled to date for the technical sessions are listed in the following:

Some Papers for the Spring Convention at Birmingham

High-Tension Oil Circuit Breaker Tests, By representatives of Alabama Power Co., General Electric Company and Westinghouse Company.

Operation of Systems with Hydro and Steam Plants, Mr. N. G. Reinicker, Supt. of Operation, Penn. Power and Light Company.

Maximum Demand Regulator, Mr. E. T. Moore, Electrical Engineer, Halcombe Steel Company.

Analysis of Waterpower Resources of South and Recommendations for Development, Mr. C. O. Lenz, Consulting Engineer.

Hydroelectric Practises and Equipment, Mr. R. H. Johnson, Electrical Designer.

Hydroelectric Practises and Equipment on Pacific Coast, Mr. S. Barfoed, Consulting Engineer.

Acceptance Tests for Hydroelectric Plants, Mr. F. H. Rogers, Hydroelectric Engineer, William H. Cramp & Sons.

Control and Regulation of Interconnected High-Tension Systems, Mr. Percy H. Thomas, Consulting Engineer.

Hydroelectric Design and Practise in the South, Mr. O. G. Thurlow, Alabama Power Co.

Symbolic Curves, Mr. J. E. Fries, Chief Engineer, Tennessee Coal, Iron & R. R. Co.

Manufacture of Phosphoric Acid in Electric Furnace, Mr. Theodore Swan, President, Federal Phosphorus Co., Mr. F. V. Andrea, Elec. Engineer, Federal Phosphorus Co.

Revising an Underground Distribution System, Mr. E. E. Moore, Engineer, Electric Bond & Share Company.

Carrier-Wave Communication on Power Lines, N. H. Slaughter, Western Electric Company.

Relaying on Duquesne System, H. P. Sleeper, Duquesne Light Company.

Effect of Certain Impurities in Storage Battery Electrolyte, G. W. Vinal, Chief, Section of Electric Chemistry, Bureau of Standards, Mr. Altrup, Bureau of Standards.

Harmonics Due to Slot Openings, C. A. M. Weber, Engineer in Charge, Small Motor Engrg. Dept., Westinghouse Elec. & Mfg. Company.
Prof. F. W. Lee, Johns Hopkins University.

New Synchronous Induction Motor, Val A. Fynn, Consulting Engineer.

Lightning Arresters, C. E. Bennett, Special Engr., Georgia Railway & Power Company.

Edison Medal for 1923 Awarded to John W. Lieb

The Edison Medal for the year 1923 has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to John William Lieb of New York, N. Y., "for the development and operation of electric central stations for illumination and power."

The Edison Medal was founded by the Edison Medal Association, composed of associates and friends of Mr. Thomas A. Edison, and is awarded annually by a committee consisting of twenty-four members of the American Institute of Electrical Engineers for "meritorious achievement in electrical science, electrical engineering, or the electrical arts."

JOHN W. LIEB —*Photo by Bachrach*

Mr. Lieb was born in Newark, N. J., in 1860. He was granted an M. E. Degree by Stevens Institute of Technology, Class of 1880, and the honorary degree of Doctor of Engineering in 1921. In 1880 he entered the employ of Brush Electric Company of Cleveland as a draftsman and in 1881 became Assistant in the Engineering Department of the Edison Electric Light Company. In 1882 Mr. Lieb became Assistant to Mr. Edison and was engaged in experimental research. He then became Electrician of the Edison Electric Illuminating Company of New York in charge of the installation and operation of the station at Pearl Street. This was pioneering of the nature of scientific research since precedents were lacking and many of the principles to be applied were but obscurely understood. In November 1882 Mr. Lieb went to Milan, Italy, to represent Mr. Edison in connection with the design, installation and operation of the Milan central station. He eventually became Technical Director of the Societa Generale Italiana di Elettricita Sistema Edison, and from 1883 to 1894 was engaged with the Italian company in power station work and in the manufacture of lamps, dynamos, motors and other apparatus. It was under his direction at Milan that some of the earliest experiments were made in parallel operation of direct-driven alternators, the operation of large synchronous motors in mill drive, and long distance transmission of high-tension alternating current by underground cables. In 1894 Mr. Lieb returned to New York as Assistant to the Vice-President of the Edison Electric Illuminating Company, becoming Vice-President and General Manager. On the organization of the New York Edison Company he was made Associate General Manager and then appointed to his present position of Vice-President, in general charge of operating, also for the affiliated electric companies in the metropolitan district. It was in 1896 that an alternating-current substation converting to direct-current was introduced using motor-generator sets. In 1898 synchronous converters were in use in several substations. About the same time steam turbines were introduced in the generating stations in New York in a preliminary way, and plans for using superheated steam were canvassed. Since 1900 Mr. Lieb has also been President of the Electrical Testing Laboratories and his influence for scientific testing and investigation has been a contribution of much importance to progress in the use of electricity.

Mr. Lieb has taken a prominent part in the work of many of the organizations in the electrical and allied fields. He is a Fellow of the American Institute of Electrical Engineers, and was President in 1904-05, and has served on many Institute committees, notably the Edison medal, Public Policy and Code of Principles of Professional Conduct. He is also a Past President of the National Electric Light Association, The Edison Pioneers, and The New York Electrical Society. He is a Fellow of the New York Academy of Sciences and Member of The American Society of Military Engineers, the American Association for the Advancement of Science, and the American Society for the Promotion of Engineering Education. Mr. Lieb's work has been recognized by many foreign societies. He is an Honorary Member of the Association of Italian Engineers and Architects and of the Association of Italian Railway Engineers. He is a Member of the Institution of Electrical Engineers of Great Britain and of the Associazione Elettrotecnica Italiana. During the war Mr. Lieb served as Chairman of the National Committee on Gas and Electric Service; Advisor to the Federal, New York State and Metropolitan Fuel Administrations, and Chairman of the Joint Fuel Committee representing the National Public Utility Association.

Medalists

The following men, whose pictures appear on the opposite page, have been recipients of the medal:

1909 Elihu Thomson. "For meritorious achievement in electrical science, engineering and arts, as exemplified in his contributions thereto during the past thirty years."

1910 Frank J. Sprague. "For meritorious achievement in electrical science, engineering and arts, as exemplified in his contributions thereto."

1911 *George Westinghouse. "For meritorious achievement in connection with the development of the alternating-current system for light and power."

1912 *William Stanley. "For meritorious achievement in invention and development of alternating-current systems and apparatus."

1913 Charles F. Brush. "For meritorious achievement in the invention and development of the series arc lighting system.

1914 *Alexander Graham Bell. "For meritorious achievement in the invention of the telephone."

1916 Nikola Tesla. "For meritorious achievement in his early original work in polyphase and high-frequency electrical currents.

1917 John J. Carty. "For his work in the science and art of telephone engineering."

1918 Benjamin G. Lamme. "For invention and development of electrical machinery."

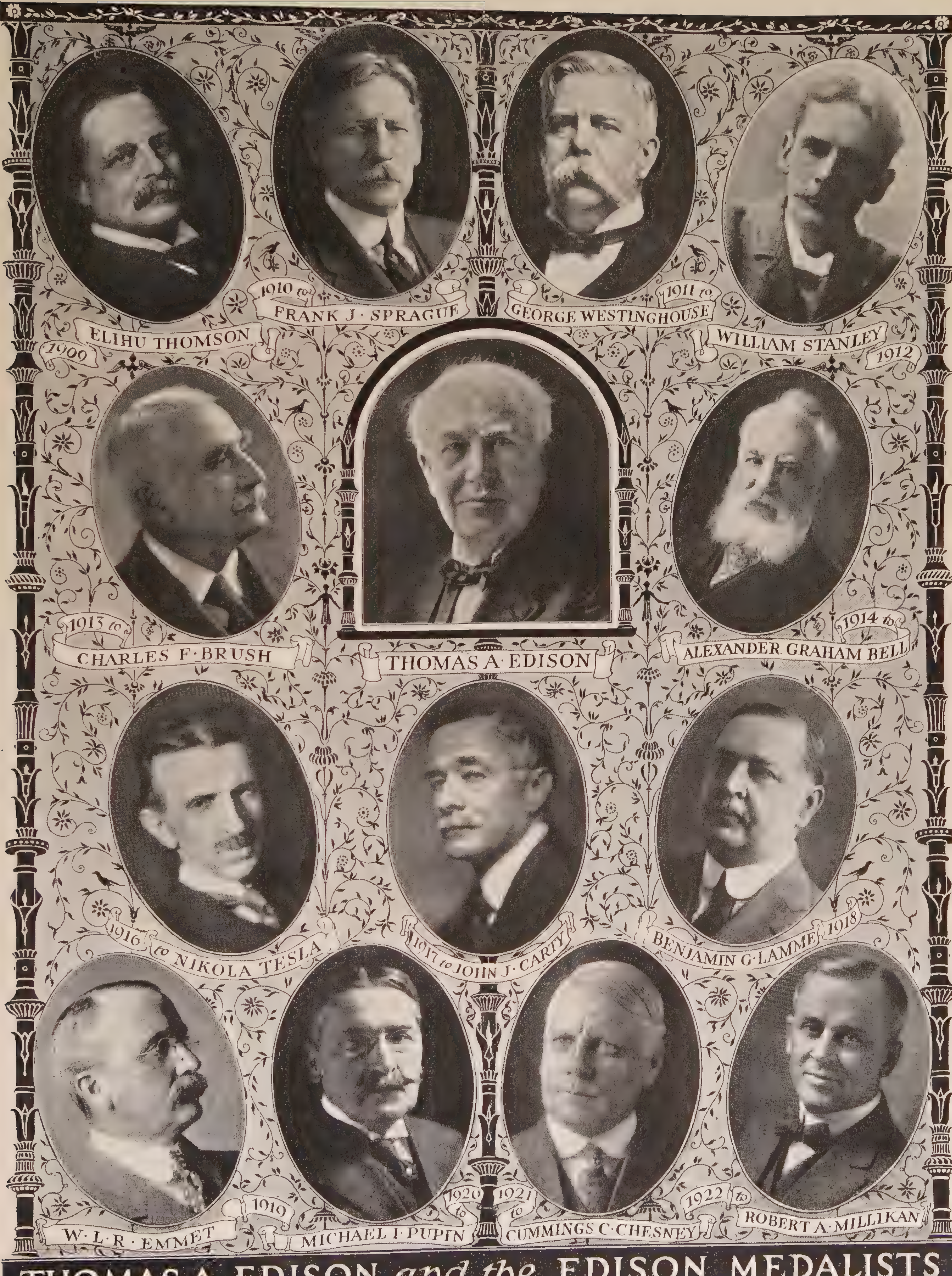
1919 W. L. R. Emmet. "For inventions and developments of electrical apparatus and prime movers."

1920 Michael I. Pupin. "For his work in mathematical physics and its application to the electrical transmission of intelligence."

1921 Cummings C. Chesney. "For early developments in alternating-current transmission."

1922 Robert Andrews Millikan. "For his experimental work in electrical science."

*Deceased.



THOMAS A · EDISON *and the* EDISON MEDALISTS

Future Section Meetings

Boston.—January 18, 1924. Subject: "High-Voltage Cable." Speaker: D. R. Roper, Superintendent of Street Department of the Commonwealth Edison Co.

Chicago.—January 14, 1924. Subject: "European Engineering Practises." Speaker: B. G. Jamieson, of the Commonwealth Edison Co.

Cincinnati.—January 10, 1924. Subject: "Radio and Carrier Current." Speaker: W. R. G. Baker, General Electric Company, Schenectady, N. Y.

February 14, 1924. Subject: "Elevator Control," by Oscar F. Shepard, President of the Shepard Elevator Co., Cincinnati,O.

Cleveland.—January 24, 1924. Subject: "Remote Control of Power by the Use of Automatic Apparatus." Speaker: Mr. Wensley, Westinghouse Electric & Mfg. Co.

February 21, 1924. "Recent Development in Electrical Industry in the Far East." Speaker: S. A. Hayes, Westinghouse Electric & Mfg. Co.

Columbus.—January 4, 1924. Telephone meeting.

January 25, 1924. Railway meeting.

February 9, 1924. Noonday luncheon.

Fort Wayne.—January 10, 1924. Subject: "Popular Lecture on Astronomy." Speaker: Prof. W. A. Cogshall, Indiana University.

January 24, 1924. A.I.E.E. Dance.

Pittsburgh.—January 15, 1924. Subject: "The Recent Electrification of the West Leechburg Steel Company." Speaker Noble Jones, General Manager, West Leechburg Steel Co.

February 19, 1924. Subject: "Motor Ratings and Application." Speaker: C. W. Falls, General Electric Company.

Pittsfield.—January 3, 1924. Subject: "Paints." Speaker: Dr. F. P. Ingalls, Chief Chemist, Masury Paint Co.

January 17, 1924. "Total Eclipse of the Sun." Speaker: B. R. Baumgardt.

February 7, 1924. Subject: "Transoceanic Radio." Speaker: F. H. Kroger.

February 14, 1924. Subject: "Motion Pictures of the Invisible." Picture Service Corp. lecture illustrated with motion pictures.

Providence.—January 4, 1924. Subject: "Some Features of Modern Large Turbine Installations." Speaker: Linn Helander, Westinghouse Elec. & Mfg. Co. This will be a joint meeting with the Power Section.

Vancouver.—January 4, 1924. Subject: "Hydroelectric Developments in Eastern British Columbia." Speaker: M. L. Wade.

February 1, 1924. Address by H. M. Lloyd on impressions gathered from recent visits to the Eastern United States and Canada.

A. I. E. E. Directors Meeting

The regular bi-monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, December 14, 1923.

There were present: Past Presidents Frank B. Jewett and William McClellan, New York; Vice-Presidents W. I. Slichter, New York, H. W. Eales, St. Louis; Managers Harold B. Smith, Worcester, Mass., A. G. Pierce, William M. McConahey, Pittsburgh, Harlan A. Pratt, Hoboken, N. J., H. M. Hobart, Schenectady, G. L. Knight, Brooklyn, N. Y., W. K. Vanderpoel, Newark, N. J.; Treasurer George A. Hamilton, Elizabeth, N. J., Secretary F. L. Hutchinson, New York.

A report of the Edison Medal Committee was presented; announcing the award by the committee of the Edison Medal for the year 1923 to Mr. John W. Lieb, "for the development and operation of electric central stations for illumination and power."

Reports were presented of meetings of the Board of Examiners held November 19 and December 10, 1923; and the actions taken at these meetings were approved. Upon the recommendation of the Board of Examiners the following action was taken: 317 Students were ordered enrolled; 107 applicants were elected to the grade of Associate; 6 applicants were elected to the grade of Member; 9 applicants were transferred to the grade of Member; 1 applicant was transferred to the grade of Fellow.

Mr. Lewis B. Stillwell was nominated, for election by the United Engineering Society, as a representative of the Institute upon the Engineering Foundation Board, for a term of three years commencing in February 1924, to succeed Mr. E. W. Rice, Jr., whose term expires at that time.

A list of members in arrears for dues for the year ending April 30, 1923, consisting of one (1) Fellow, 45 Members, and 620 Associates, was presented; and the Secretary was authorized to remove from the membership list on December 31, 1923, the names of all those whose dues remain unpaid at that time and who have not indicated a desire to continue membership and requested an extension of time for payment of the dues.

Upon the recommendation of Vice-President R. F. Schuchardt, of Chicago, the Board voted to change the location of the 1924 Annual Convention from a hotel at Evanston, Ill., formerly decided upon and now considered of insufficient capacity, to the Edgewater Beach Hotel, Chicago, and that the exact dates of the convention be definitely authorized as June 23-27, 1924.

Upon the recommendation of President Ryan, Vice-President Macdonald of the Pacific District, and the Executive Committee of the Los Angeles Section, it was voted that the 1924 Pacific Coast Convention be held during the week beginning October 13, at Pasadena, California.

Authorization was given for the establishment of a Student Branch of the Institute at the University of Utah, at the University of South Dakota, and at the Catholic University of America.

Amendments to the by-laws of the Institute, in order to cover policies that have been adopted by the Board of Directors from time to time, were adopted. These amendments will be included in the 1924 Year Book.

Mr. Edward D. Adams was reappointed a representative of the Institute upon the Library Board, United Engineering Society, for the term of four years commencing January 1, 1924.

The Board considered a report of a special joint committee that had been appointed to recommend methods of cooperation of the four Founder Societies, and voted to adopt the recommendation of the committee to the effect that a permament Joint Conference Committee be established, consisting of the Presidents and the Secretaries of the four Founder Societies, as an "effective means of giving preliminary consideration to the various problems, of suggesting the policy to be followed in each case and of recommending the procedure for carrying out these policies, using as far as practicable existing agencies. The first chairman of the committee, for a term of one year, should be the President of the American Society of Civil Engineers, and thereafter the President of each of the four Founder Societies in order of seniority. Whenever a President or a Secretary cannot attend a meeting of the committee, he should appoint an alternate."

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

The New Lending Service of the Library

The Library Board has long wished to establish a lending department in the Engineering Societies Library, but has found it impossible to do so, as its resources were not large enough to permit the necessary duplication of books. Recently, however, a plan has been proposed for lending books on a rental basis. This plan, having been endorsed by the Founder Societies and the United Engineering Society, has been adopted.

The Library now has available for lending a good collection of modern up to date American books on engineering. Additions

will be made as demands indicate and it is hoped that it will be possible to fill any reasonable requests. These books will be lent, by mail or express, to members in North America. It is hoped that members, who seldom can visit the Library, will find this service convenient, and that they will make full use of it. If members avail themselves freely of the service, it is expected that the receipts from loans will justify the continuance of the plan. Members can also assist materially by returning books and paying bills promptly, and by making requests as definite as possible, so that correspondence may be reduced to a minimum, and the overhead expense kept low.

As the collection will be constantly changing, through the withdrawal of unused books and the addition of new ones, it will not be possible to print a catalog. Most of the recent books published in this country are available. If a member does not have a particular book in mind, but wishes one on some subject, the Director will be glad to send the best book available.

The rules that follow have been adopted tentatively. Members are invited to suggest changes that would give them service better adapted to their needs.

RULES

1: Books will be lent to members of the Founder Societies and of other societies that contribute regularly to the support of the Library.

2. A rental of five cents a day will be charged for each volume. An allowance will be made for time of transit, based on the average time of mail from New York.

3. Transportation charges and insurance will be charged to the borrower.

4. The Library will be responsible for losses during shipment to the borrower. The borrower will be responsible for the return of books to the Library.

5. All damage, except reasonable wear, will be charged to the borrower.

6. Members may purchase, at the publishers' price, any books that they borrow. If the Library is notified within ten days after receipt of the book, no rental or transportation will be charged.

In asking for loans members will please indicate clearly the books wanted. They should also state the Society to which they belong, and the address to which the books are to be sent.

Correspondence should be addressed to the Engineering Societies Library, 29 West Thirty-ninth Street, New York, N.Y.

At present the Library can not lend books in foreign languages. Periodicals and the Transactions of societies are also not available. Photoprint copies of these will be supplied at cost, as in the past.

Nomination and Election of Institute Officers for 1924-1925

As provided in Section 19 of the Institute By-Laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1924, by the petition or by the separate endorsement in writing, of not less than twenty-five members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1924. For the conveniences of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available. A member is not limited in the number of candidates he may endorse in this manner.

The officers to be elected are: A President and a Treasurer for the term of one year each, five Vice-Presidents for the term of two years each (one from each of the odd numbered geographical districts), and three Managers for the term of four years each.

The five odd numbered districts from which Vice-Presidents are to be chosen at the May 1924 election are as follows:

1. North Eastern: Maine, New Hampshire, Vermont, New York, Massachusetts, Rhode Island, Connecticut.

3. New York City: Territory of the New York Section; also Canal Zone, Porto Rico and all foreign countries except Canada.

5. Great Lakes: Wisconsin, Michigan, Illinois and Indiana.

7. South West: Texas, Oklahoma, New Mexico, Kansas, Missouri and Arkansas.

9. North West: Washington, Montana, Oregon Idaho, Utah and Alaska.

According to the revised Constitution, while one Vice-President must be elected from each of the five odd numbered districts, this does not debar members in one district, if they so wish. from nominating and voting for a candidate in another district. When the votes are counted the candidate for Vice-President having the largest vote in each district will be elected to that particular office for that district, irrespective of the fact that he may have polled a smaller number of votes than a candidate standing second in another district.

For the information of members the full text of revised sections of the Constitution and By-Laws applying to Officers, nominations, elections, etc., are printed below:

CONSTITUTION

Sec. 23. The officers of the Institute shall be a President, one Vice-President from each geographical district as defined in the By-Laws, twelve Managers, a Secretary and a Treasurer.

Sec. 24. The President, the Secretary and the Treasurer shall hold office for one year, the Vice-Presidents for two years and the Managers for four years. The President and Managers shall not be eligible for immediate re-election to the same office. No Vice-President or Manager who has served continuously in one or more offices, and whose combined terms shall have aggregated six years or more shall be eligible for immediate election to the office of Manager or Vice-President. At each Annual Meeting the President, the requisite number of Vice-Presidents to fill vacancies caused by expiration of terms, three Managers and the Treasurer shall be elected by the membership, and their terms of office shall commence on the first of August next succeeding their election..............

Sec. 24A. At the election of Vice-Presidents held in 1921 there shall be elected one Vice-President from each geographical district, those from the odd-numbered districts to serve for one year each, and those from the even-numbered districts two years each. All Vice-Presidents elected thereafter shall serve for two years each. In the event of a change in the geographical districts, the Vice-Presidents then in office shall complete their terms. In case of revisions of the geographical districts, the Board of Directors shall have the power to elect a Vice-President from each district not represented to serve until the next election covering these districts.

BY-LAWS

Sec. 19. In addition to the names of the incumbents of office the Secretary shall publish on the form showing offices to be filled at the ensuing annual election in May provided for in Article VI, of the Constitution, the names, as candidates for nomination, of such members of the Institute as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than twenty-five members, received by the Secretary of the Institute in writing by January twenty-fifth of each year; provided, however, that any candidate proposed for nomination by petition may withdraw his name by written communication to the Secretary, and any name so withdrawn prior to the printing of the form shall not be published.

The names of such candidates for nomination shall be grouped alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the December and January issue of each year's Journal and shall be reproduced on the form above referred to.

Sec. 21. There shall be ten geographical districts grouped as follows: (For the balance of this Section describing districts see By-Laws and map.)

Sec. 21A. Should the territory of any Institute Section lie in more than one geographical district as defined above, then the entire territory of said Section shall be considered as belonging to the geographical district in which the headquarters of the Section are located.

Fundamental Problems of Hydroelectric Development

At the annual meeting of the American Society of Mechanical Engineers held in New York, December 3-6, one session was devoted to a discussion of hydroelectric power, in cooperation with the American Society of Civil Engineers and the American Institute of Electrical Engineers. The meeting was opened by President Harrington of the A. S. M. E. who, after referring to the misapprehension of the public concerning the waterpower situation, turned the meeting over to Mr. L. B. Stillwell who presided. A paper was presented by Mr. John R. Freeman, of Providence, and prepared discussion by Col. John P. Hogan, Mr. George A. Orrok, and Mr. H. W. Buck, all of New York City. Extemperaneous discussion was offered by Mr. William M. White, Milwaukee, Mr. J. P. J. Williams, and Mr. T. Kennard Thomson, New York.

In his introductory remarks Mr. Stillwell stated that the utilization of water power by electric transmission already has made a very great contribution to the developed wealth of our country and to the well-being of our people. Very much remains to be done. But the hydraulic machinery to convert the energy of falling water into mechanical power and the electric generators, transformers, insulators and other equipment to convert that power into electric energy, transmit it over great distances and distribute it at low unit costs for a vast variety of useful purposes, are so far perfected that few fields for the investment of capital today are more attractive than that which involves dependence upon this comparatively new art. Today, hydroelectric plants aggregating more than 8,000,000 horse power are in use in the United States. Surely, those who have contributed and are contributing to progress in the hydroelectric art are fortunate not only that their work has been keenly interesting as regards the science and engineering involved but also that it has resulted in so great a contribution to material progress and to the well-being of the American people.

Paper by John R. Freeman

The first paper was presented by Mr. Freeman, from which the following brief abstracts are taken:

We are now in the midst of the greatest activity ever known in hydroelectric development and problems of unprecedented magnitude are before us.

This kind of a meeting may serve a useful purpose far beyond that of interchange of information between specialists in power development, if it can interest engineers working outside of this special field in the broad aspects of some of these fundamental problems.

Agreement is not to be expected among all of us coming, as we do, from different fields, with different points of view; nor can we settle the great problems here. Our chief purpose must be to promote and direct discussions along useful lines among engineers, business men, and those in public life.

The very fundamentals can be quickly stated:

1. A hydroelectric prospect must show a profit on the investment.
2. It should be so developed as to contribute to public welfare in the highest degree.

These principles seem so self-evident as to require no extended discussion, but to prove up, on their application to a particular prospect, may require an enormous amount of work.

After reviewing the costs for water power obtaining fifty years ago at the prominent New England water power sites the speaker said that fifty years have brought a wonderful increase in the amount of power used and in methods of developing it, but costs per horsepower in the broad view show small change. The cost of coal has doubled, but higher steam pressures, larger power units, the steam turbine, and the economies of the central station have cut coal consumption per horsepower-hour in half.

In waterpower development the unit costs per pound for machinery and per cubic yard for structural material have doubled. Although the efficiency of the hydro unit has increased at best only from 83 per cent to 93 per cent (and for some time has been close to the end of the road), the costs of installation, maintenance, and supervision have been held down by a wonderful concentration of power into single units, under terrific head, and by a revolution in the features of design for large developments, so that with all these changes there has been remarkably small change in 50 years in cost of either hydro or steam power in large quantity, reckoned at the prime mover.

And in all these new schemes of superpower—St. Lawrence power or steam stations at the mouth of the mine—I see no chance for any substantial reduction in power cost at wholesale below that which we now enjoy in either the near or the distant future.

Few of the largest water turbines in Lowell or Lawrence were of more than 200 h.p. each, 30 years ago. An 80-in. Swain wheel of about 800 h.p. put in at Lawrence about 45 years ago was regarded as a monster, as "the most powerful turbine ever built," and finally its buckets (of cast-in plates) broke loose, unable to stand the strain of 30 ft. head.

The one turbine which I saw started at Pit River, California, last October, under about 450 ft. head, had more power (40,000 h.p.) than all 65 of the Lawrence turbines combined, plus all of the Lowell turbines. And a single one of the recent turbines at the Queenston-Chippawa plant developed 60,000 h.p., or more than the total obtained in all three of the old water-power cities—Lawrence, Lowell and Manchester—from the Merrimac River, which we used to say was "the hardest-worked river in the world."

The changes of 30 years are far less in the cost of power than in the scale on which it is developed, its widespread distribution, and its ever-increasing uses.

Change of Method

The most fundamental changes in scheme for developing a great waterpower that have come in the past 30 years have come from the distribution of power by electricity. Then *water was distributed* to the turbines, now the *power is distributed* to the machines in the factory. The author then summarized the mechanical changes which have in recent years revolutionized the design of hydroelectric power plants.

Other changes of even greater importance to the builder of a new factory have been brought about by the distribution of power by electricity throughout all parts of the factory and throughout city and county. Now the central station and the public-service corporation relieve the founder of a new industry from raising the large sum necessary for developing a water power or for buying boilers and engines. His capital is thereby conserved for building a larger factory, or if the new enterprise is something of a venture, he can try it out with a smaller investment. Moreover the economies of large power units, of wholesale scale of operation, and the diversity factor in a widespread system permit him to buy his power cheaper than he could make it; and more than one large factory with a good steam power plant already installed has found economy in shutting it down and buying from the public service circuits

One of the most fundamental changes of all is that of the view of the public toward waterpower development. Formerly its only interest was in welcoming the development of power because of the benefits from employment that followed in its train, and with little or no thought of public control. Now where any general public service is to be given there is oversight by public officials at almost every step in development.

Good practical methods for safeguarding the public from unreasonable rates and invested capital from cutthroat competition or political confiscation are being worked out through public-service commissions, which promise much better service

and much lower costs than possible through public ownership and a management under political control.

INTERCONNECTION

In hydroelectric practise the facility of long-distance transportation of power is the outstanding achievement of the past 20 years, and one of the most interesting features is the way steam power and waterpower installations at widely separated places, each pumping current into opposite ends of the same line, have come to supplement each other, economizing both power and transmission, uniting and interchanging the variable power developed in the mountains or foothills from water which is plentiful in springtime but scanty in midsummer, with steam power developed at the seacoast from seaborne coal or oil. The electric current flows with equal facility in either direction.

Just now there is some confusion of thought in the present popular interest in superpower schemes between "superpower" from great new stations and the *interconnection* of central stations by which one station can help another and by which the steam station—far more flexible than the hydro in taking overload—can help out the hydro station in low-water seasons, while the hydro, in its flush times, can save coal to the steam station.

VALUE OF A WATERPOWER SITE

There is a widespread notion that almost any waterfall can be turned by hydroelectric development into a never-ending, ever-flowing stream of gold, with small understanding of the amount of capital that must be buried beyond recall in such a venture, and on which interest must be paid or income found if capital is to be conserved.

Hydroelectric development differs from steam-electric development or other power development in that *the big expenditure for waterpower comes mainly all in one bunch*, whereas with steam it comes step by step, as needed, for almost immediate use.

In waterpower development the site, the water rights, the flowage, the dam, the power house foundations, and the larger part of expenditure for turbines, electric apparatus, switchboard, and transmission line must be made in full at the start, and if customers are not already signed up for sufficient kilowatts to pay fixed charges, the prospects are uninviting.

I wish to fix attention strongly on the fact that the value of a prospective hydroelectric site is *not in the water and its fall*, but *solely in the use to which this power can be put* and the rate at which the total output can be absorbed in industry, so as to pay interest upon the capital invested.

Conservation of capital always should be considered along with the conservation of natural resources throughout the design. This frequently will lead to a departure from the line of engineering development that would be ideal at a given site, because of the menace of an unsatisfied interest charge upon capacity provided but not promptly put to use.

CENTRALIZING VS. SCATTERING INDUSTRIES

Electrical transmission of both steam and hydroelectric power is now helping greatly in the economical establishment of new industries, but up to date it has been favoring further concentration in cities. It would be well if something could be done to start a movement in the opposite direction. As the network of power lines becomes more and more interconnected with the smaller communities, giving to them an ample supply of cheap and dependable power many kinds of industry might again turn to the country village, attracted by lessened real-estate values, fewer strikes, lesser taxes, and by those benefits difficult of precise appraisal that come from the wholesome conditions of family life and social provilege that may be found by operatives in the smaller communities. A wire can carry current in either direction, and there are many cases where favors could be shown by the public in smaller burdens of taxation, etc., etc., that might turn the scale.

PUBLIC RELATIONS

After prolonged taking of testimony and discussion we now have the Federal Power Act, permitting and encouraging power development from rivers flowing through the public lands of the Great West. Before obtaining this some very intense misunderstandings had to be cleared up. It seems to be working well.

One of the great problems of water-power development is the education of the general public to understand the costs added by overhead, by steam reserve, by peak loads, by stand-by charges, and by distribution to the small consumer, by the expenses of measuring his draft, collecting his monthly account, and of developing in large blocks safely ahead of the demand, by maintaining a readiness to serve during drought, storm, flood, or fire, by elaborate inter-connections with various widely scattered plants.

New York State has by recent referendum voted 2 to 1 against permitting a microscopic proportion of its state lands to be flooded for waterpower reservoirs and by this act also has forbidden place and passage for power house and transmission lines upon its forest preserves; an action strangely at variance with the recent policy of the National Government. There appears to have been an inseparable mixture of motives in this large adverse vote, but the most powerful motive seems to have been a broadly cultivated idea that this defeat would preserve a great opportunity for waterpower development under state ownership, with *no real understanding of the facts by the voters at large.*

At the recent Richmond Convention of the American Society of Civil Engineers there was presented an extremely interesting and instructive talk by Mr. Wm. S. Lee, on the present widespread interconnection of power systems in the Carolinas and other southeastern states, showing how this widespread benefit of a superpower system came mainly from the transfer of power in a great chain of systems *not by a long leap from one end of the system to the far-distant end*, but by passing surplus from one system merely *to the next in line*; in time of flood, drought, or breakdown, or in finding temporary use for the surplus of a new plant in helping an overloaded neighbor until he too could build larger, and how all of this was in the interest of the public.

Can any reasonable man, familiar with the facts and with human nature, doubt that these far-flung developments can be most rapidly advanced and best carried on by great corporations, under a carefully guarded governmental supervision, better than as an enterprise wholly in state or federal hands and largely dominated by politicians?

Things have now come to the stage where the most fundamental problem of hydroelectric development is the education of the public by making plain the facts.

Who can tell how long the call for this long-distance transmission is to be held back by the success of the mercury-vapor turbine and by the success of those new steam turbines at 1200 lb.? Will the next great advance come from these improved heat engines or from improvement in long-distance electrical transmission? This brings us forthwith into the discussion of transmitting power to Boston and New York from the St. Lawrence.

Whatever may be the present obstacles to developing Saint Lawrence power, I believe it certain as the sunrise that sooner or later they will be overcome; and it is plain beyond all argument that it is better for the two nations that this power be used to conserve the coal supply for posterity instead of running to waste. Nevertheless I fear that 10 or 20 years must pass before any important economy in power cost in New England or around New York City can come from this direction. High-pressure steam, cheaper coal, and perhaps the mercury turbine and the Diesel engine, may delay the day for service 300 miles away.

There is more than five million horse power now running to waste along the St. Lawrence. It is hard even for an engineer to comprehend what five millions of horse power of energy means, and difficult to translate it into the terms of every-day life. This is about the sum total of electrical generating

capacity today in all the central stations, steam and hydro, of New England, New York, New Jersey, and Pennsylvania. And this St. Lawrence power being 24-hour power with ample storage for conservation, is equivalent to providing about three times the number of kilowatt-hours per year now used in lighting, railways, manufacturing, chemistry and metallurgy, etc., throughout this vast industrial and commercial region.

How soon do New York and New England need it? What will it cost here? How much can we pay for it? How much of it is needed here? There are its fundamental problems here.

DISCUSSION

Mr. John P. Hogan discussed the need of accurate engineering data before proceeding with the development. A great many hydroelectric developments have been financial failures, and the majority of failures in this class have been due to two principal causes; (1) overestimation of the available water supply, and (2) underestimation of the cost.

There are no rainfall or run-off records in this country of sufficient duration to enable an absolute prediction to be made of the available water supply. The best that can be done in any case is an approximation, and the accuracy of this approximation will depend upon the length of record of run-off available together with the contributory evidence on both rainfall and run-off streams of similar location and characteristics.

Up to recent years the hydroelectric project which was properly explored prior to construction has been the exception rather than the rule. The proper carrying out of the preparatory work on a hydroelectric development is always expensive. It is non-productive work and returns no immediate revenue, and there is usually a constant effort on the part of the owner or developer to cut down expenses.

Hydroelectric development is in the long run much preferable to steam even at equal cost. It is a fact, however, that ill-considered and unprofitable hydroelectric developments in the past have made it more difficult to finance meritorious projects at the present time, and it is necessary that we profit by the mistakes of the past in order to build better for the future.

Mr. George A. Orrak discussed the relative costs of water power and steam plants and presented some curves showing the relation between steam generation at the load center and waterpower generation at a distance of 300 miles, with varying coal prices.

For $4 coal and 100 per cent load factor, corresponding to an output of 1,750,000,000 kw-hr. per annum, the total cost of steam generated in the large center and water power generated 300 miles away and transmitted to the city are about even when the cost of the hydraulic generating station does not exceed $150 per kw. installed. This point with $6 coal is about equal to $200 per kw. of water installation, and with $8.50 coal to $250 per kw. of water installation. The transmission cost does not exceed 20 per cent of the total cost of waterpower and minor variations in distance or cost affect but little the location of the curves, nevertheless water power, even when more costly than steam power, has a place where coal is costly and may be impossible to obtain. The great extension of hydroelectric stations in certain European countries can only be justified by their lack of coal supplies.

Mr. Harold W. Buck discussed the subject of interconnection of power systems. One of the greatest movements which is taking place today among the great power companies of the country is the extension of their distribution systems over vast territories and of the interconnection between these systems.

Some twenty years ago the Niagara Falls Power Company was engaged in the distribution of 200,000 h. p. over a territory of some 10,000 square miles. That had elements of superpower in it, itself. Ten years ago, in the State of California, there was a network of transmission which was practically 700 miles from its northerly limit to its southerly limit. At the present time the entire states of North and South Carolina are connected solidly with a gridiron of lines operated by many water powers and some steam reserve.

Within recent months, I am informed that certain transmission links have been completed so that power can be theoretically transmitted from St. Paul to Chicago, from Chicago to Indianapolis, Indianapolis to Cincinnati, Cincinnati to Louisville, Louisville to Nashville, Nashville to Birmingham, and Birmingham to Atlanta, through the systems of the Northern States Power Company, the Chicago Edison, the Ohio Power, the Kentucky and West Virginia Power Company, the Kentucky Utilities, the Tennessee Power, the Tennessee Eastern Power, the Alabama Power, and the Georgia Railway and Power Company. That is an enormous step in advance in the line of superpower, which is already today in existence.

I do not believe, however, that this superpower idea is going to materially reduce the cost of power. I do not see that it is working that way in any respect. It is merely increasing the available supply of power and making it possible for the isolated manufacturer who now operates an efficient plant to connect his works to the network and derive the very great benefit which will result from that.

But the greatest and most important relation which this extension and interconnection of lines has to waterpower is in making certain water powers available at all. I think the discussion as to which is the cheaper, steam or waterpower, is a great fallacy. It befogs the issue and is not the question before us at all. Waterpower, to be made available, at least in the Eastern States of this country, must, I think, in almost every case, be developed and operated in conjunction with a steam plant, and the question before us is: How much of the stream flow of any given river is justified in development, and what proportion must be carried by steam?

Some brief oral discussions were next presented, after which Chairman Stillwell closed the meeting with the recommendation that the A. I. E. E., through a committee, make a thorough study of frequency with a view to such standardization as will avoid waste and give ultimately an interconnected system throughout perhaps the whole country representing the best economy possible to the art.

Bombay Association Holds Second Annual Meeting

The second annual meeting of the Bombay Association of the Institution of Engineers was held on November 13 and 14, 1923, at Bombay, India. Two papers were presented during the morning sessions, the first, "Foundations in Black Cotton Soils or Regur," by N. N. Ayyangar, and the second "An Examination on the Draft Indian Boiler Regulations," by D. R. MacIntosh. One afternoon session was devoted to a steamship trip with visit to the Engineering Works and the second was occupied by a trip through H. M's. Mint. The meeting closed with a dinner given at the Taj Mahal Palace Hotel, at 8 p.m., at which a number of prominent government officials were present, including His Excellency, Sir George Lloyd, Governor of Bombay. During his speech he called attention to the great number of extensive engineering projects being developed in India, to the need of obtaining the services of the very best engineering talent and to the fact that in selecting the proper men to execute the work no prejudice as to race or color could be permitted.

Meeting of Council of International Electrotechnical Commission in Paris

A meeting of the Council of the International Electrotechnical Commission was held in Paris, December 3rd last. At this meeting Dr. C. O. Mailloux of New York, who has been President of the Commission since 1919, retired from that office and was succeeded by Signore Guido Semenza of Milan who is well known in this country. Subsequent to the election of Mr.

Semenza, Dr. Mailloux was elected by acclamation Honorary President of the Commission. This distinction which has come to Dr. Mailloux as a result of his invaluable services to the Commission since its inception in 1906 is very gratifying to Dr. Mailloux's many friends.

By a revision of the statutes, a new special committee was constituted called the "Comité d' Action" which will function, in certain matters, for the Commission in intervals between the Plenary Meetings. As the immediate Past President of the Commission, Dr. Mailloux becomes a member of this committee.

Three new National Committees, recently formed, were admitted to the Commission. One was the resuscitated Hungarian National Committee; another was the National Committee of Czecho-Slovakia; and the third, the new Polish National Committee.

The meeting was in all respects a very successful one.

AMERICAN ENGINEERING COUNCIL

SOME FEATURES OF ANNUAL MEETING OF AMERICAN ENGINEERING COUNCIL

Secretary Herbert Hoover of the Department of Commerce, President Nicholas Murray Butler of Columbia University, and Dwight F. Davis, Assistant Secretary of War, will be the chief speakers at a dinner in Washington, Thursday evening, January 10, to be attended by engineers. public officials, representatives of the Army and Navy, educators and economists from all over the United States.

The event will be one of a series lasting a week in connection with the annual meeting of the American Engineering Council of the Federated American Engineering Societies. Secretary Hoover is expected to discuss the work of the Department of Commerce as it relates to the nation's vast engineering projects.

Dr. Butler will describe the growing influence of engineers in modern life and their influence upon world affairs. Speaking on "The Industrial Preparedness Program of the War Department," Mr. Davis will tell how engineering organizations may be helpful in the execution of the national program. Dean Mortimer E. Cooley of the University of Michigan, retiring president of the American Engineering Council, will preside. Heads of national engineering organizations from New York and cities of the West and South, in addition to representatives of numerous local societies, will attend.

A central feature of the week's meetings is a Public Works Conference to be held on Wednesday, January 9. Delegates from more than 200 engineering and allied bodies, including the American Institute of Architects, will be present.

The purpose of the Conference is to urge the adoption by Congress of that part of the Brown Plan of Government Reorganization which provides for the making over of the Department of the Interior, the proposed arrangement grouping the functions of the Department under a Division of Public Works and a Division of the Public Domain. The U. S. Patent Office and the Bureau of Mines would be transferred from the Department of the Interior to the Department of Commerce.

G. S. WILLIAMS DELIVERS ADDRESSES

Outstanding problems of river and harbor development were discussed at the session of the National Rivers and Harbors Congress which was held in Washington, December 5.

Gardner S. Williams, vice-president of the American Engineering Council, and Mr. Robert Isham Randolph of Chicago, defended the plan for the diversion of water through the Chicago Sanitary Canal in addresses delivered on Wednesday evening. Attacking the diversion was William George Bruce, president of the Great Lakes Harbor Association, and Major C. Alfred Maguire of Toronto.

Other important addresses were delivered by Ambassador Hannihara of Japan, Senator Joseph E. Ransdell of Louisiana, Major General Lansing H. Beach, chief of engineers; Representative Samuel E. Winslow of Massachusetts, John H. Small, president of the Congress.

While in Washington Major Williams spoke before the annual meeting of the American Institute of Chemical Engineers on the subject, "The Engineer in Public Affairs." He then went to New York to hold a meeting of his committee on registration of engineers and to attend other important Federation Committee meetings that will be held there.

American Engineering Standards Committee

PROGRESS OF INDUSTRIAL STANDARDIZATION DURING 1923

BY A. W. WHITNEY

Chairman American Engineering Standards Committee

During the past year, industrial standardization has continued to develop as one of the most active and important phases of American industry. Progress has been made in the standardization of raw materials, manufacturing processes and finished products. This is equally true whether looked at from the point of view of the factory, of the industrial or technical association, or of a national movement.

A striking development is the increased systematic use of specifications in public purchases, notably in the federal and in several of the state governments. The National Association of Purchasing Agents and the National Council of Governmental Purchasing Agents are devoting much time and attention to the subject. At the direction of Mr. Hoover, the Department of Commerce is preparing to publish a "Dictionary of Specifications for Public Purchase," which will make easily available information as to what specifications are in existence, to what classes of use they apply, and how they may be obtained.

The Federal Specifications Board has completed the second year of its activity. In this, the American Engineering Standards Committee has cooperated by obtaining criticisms from the various interested industries of proposed specifications of the Federal Government before the specifications are finally adopted by the Board. To date, the Board has adopted approximately ninety specifications, and the Committee has secured criticism of industry on about the same number. From these systematic efforts to bring governmental purchases in line with the best commercial practise, important economies both to industry and government are resulting.

The Division of Simplified Practise of the Department of Commerce continues to exert a most stimulating influence on the standardization movement, particularly in emphasizing the efficiency results of standardization to the business man.

Through the organization of the American Marine Standards Committee, work has been initiated in this important industry. Very little in this field has heretofore been done in this country, although very considerable activity has been going on for some time in Germany and Great Britain.

The most striking aspect of the movement for industrial standardization is the development of standardization on a national scale. More than 150 undertakings now have official status before the American Engineering Standards Committee, the national clearing-house for standardization. Fifty standards have received final approval by the Committee, twenty-two of

which were approved during 1923. The importance of broadly democratic methods followed in this clearing-house work is receiving increasingly widespread recognition. In it all parties concerned with any standard, producers, consumers, and representatives of the public and government, participate (1) in deciding whether the work should be undertaken at all, (2) in formulating the standard, and (3) in its ultimate approval. Thus the industries are developing and using such standards as best fits their needs, without danger of such technical industrial matters becoming subject to legal enforcement or to governmental pressure. Is it not probable that many other of our important industrial problems will find their solutions by closely analagous methods?

In July, the second conference of the national industrial standardizing bodies was held in Switzerland, where thirteen of the more important industrial nations of Europe and America were represented. Important progress was made in developing cooperation between the various national bodies, particularly in regard to the early release to each other of information on work in progress. Information on the status of all projects in hand is now regularly interchanged between the various bodies. Provision was made for continuing the work of the conference on the many problems of common interest through a continuing loose-knit organization.

There are now national industrial standardizing organizations in sixteen countries: Australia, Austria, Belgium, Canada, Czecho-Slovakia, France, Germany, Great Britain, Holland, Hungary, Italy, Japan, Norway, Sweden, Switzerland, and the United States. Of these, the work in Great Britain, Germany and the United States is the most extensive, as would be expected from the scale of the industrial development in these countries.

The extensive standardization work going on in Germany continues to present many interesting phases. Practically every important manufacturing concern in that country is actively engaged in the work, and more than a thousand companies have formal standardization organizations within their own works. Approximately seven hundred national German standards have been approved by the central national standardizing body. These are only standards in which several industries are concerned. Standardization engineering is now a recognized profession in Germany. Some of the consulting engineering firms specialize on standardization work. Through their work on trade catalogs, these consulting engineers, among other things, are introducing standardization into sales policies and sales organizations.

Of interest not only in its relation to international standardization, but also on account of its bearing on the use of specifications in foreign trade, is the resolution passed by the last conference of the Pan American Union, where it was decided "That a conference on standardization of specifications of materials, tools, machinery and supplies be held with a view to reaching agreements which may be embodied in Inter-American conventions on this subject." This projected movement will be watched with great interest by American industries.

Standardization continues to play a more and more important role in the activities of trade associations. The subject is treated at length in the book on Trade "Association Activities" issued by the Department of Commerce during the year. It is of more than passing interest that the Supreme Court in a recent decision in regard to trade association activities, explicitly recognized standardization as being in the public interest.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (NOVEMBER 1-30, 1923)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

VECTOR ANALYSIS.

By C. Runge. N. Y., E. P. Dutton & Co., n. d. 226 pp., 8 x 5 in., cloth. $3.50.

A complete, logical treatment of the vectorial analysis of three dimensions, presented in convenient form, suitable for serious students of mathematics. The book is based largely on the work of Grassman, but uses a simplified notation. A second volume, on the analysis of four and more dimensions, is promised.

TREATISE ON ELECTRO-METALLURGY.

By Walter G. McMillan. 4th edition, revised and enlarged by W. R. Cooper. Lond., Charles Griffin & Co.; Phila., J. B. Lippincott Co., 1923. 449 pp., illus., diagrs., tables, 9 x 6 in., cloth. 21s.

This standard work, which has been out of print since 1919 is now reissued in revised form. The original intention of the author to provide a technological treatment rather than a technical one has, however, been preserved.

The new edition takes account of the many recent advances in electro-metallurgy, particularly progress in depositing cobalt, extracting zinc and refining copper. Throughout, minor corrections have been made when necessary.

SIDELIGHTS ON RELATIVITY.

By Albert Einstein. N. Y., E. P. Dutton & Co., n. d. 56 pp., 8 x 5 in., cloth. $1.50.

Two lectures by Dr. Einstein, discussing in non-mathematical language certain matters connected with relativity. The first lecture, entitled "Ether and the Theory of Relativity," was delivered in 1920 at the University of Leyden. The second discourse, on "Geometry and Experience," was given in 1921 at the Berlin Academy of Sciences.

PRACTICAL CONTROL OF ELECTRICAL ENERGY.

By Alfred George Collis. Lond., Henry Frowde, & Hodder & Stoughton, 1923. (Oxford Technical publications). 160 pp., illus., diagrs., 9 x 6 in., cloth. $3.50. (Gift of Oxford University Press. American Branch).

A collection of data relating to the design of measuring instruments and systems, protective apparatus, switches and other devices used for controlling electric power in everyday practise. Mathematical complexities are avoided, the data and principles

being presented in simple language; and the treatment of the subject is descriptive.

POULSEN ARC GENERATOR.

By C. F. Elwell. Lond., Ernest Benn, 1923. 192 pp., illus., diagrs., port., 9 x 6 in., cloth. 18 s.

This, apparently the first book on its subject, is not intended as a technical treatise on this generator, but rather as an account of a machine which has rendered great service in the twenty years of its existence. The book gives a summary of the theory of the generator, describes practise, in design and construction, and treats its applications to radio-communication and as a measuring apparatus. A good bibliography is included.

MECHANICAL APPLIANCES, MECHANICAL MOVEMENTS AND NOVELTIES OF CONSTRUCTION.

By Gardner D. Hiscox. 5th edition. N. Y. Norman W. Henley Publishing Co., 1923. 412 pp., illus., 9 x 6 in., cloth. $4.00.

This book contains nearly a thousand mechanical appliances for the generation, transmission and measurement of power, for gearing machinery and for various industrial purposes. Describes many attempts to obtain perpetual motion. The descriptions are brief and are accompanied by sketches. This edition is largely a reprint of edition four, with an added section on radio telephony and telegraphy.

DIE MATERIALPRUFUNG DER ISOLIERSTOFFE DER ELEKTROTECHNIK.

By Walter Demuth. 2d edition. Berlin, Julius Springer, 1923. 254 pp., illus., diagrs., 9 x 6 in., boards. $3.00.

This manual aims to provide the practising engineer with a guide to satisfactory methods of testing insulating materials and also a summary of the properties and uses of the principal insulators. The book is in two sections; the first being on solid insulating materials, the second on liquid ones, including varnishes, etc. Methods for mechanical, physical, chemical and electrical tests are described in detail.

HYDROELECTRIC POWER STATIONS.

By David B. Rushmore and Eric A. Lof. 2d edition. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. 830 pp., illus., diagrs., tables, 9 x 6 in., cloth. $7.50.

This book treats of the problems which must be solved in connection with the construction and management of a hydroelectric power station, so that the manager or engineer may select power equipment and fully understand the economic factors that enter into each solution. The subject is approached from the point of view of the practical engineer; both hydraulic and electrical questions are considered, including all matters essential to design and operation.

The new edition has been practically rewritten to meet the recent important changes in practise.

HANDBOOK OF INDUSTRIAL OIL ENGINEERING.

By John Rome Battle. 2d edition. Phila., J. B. Lippincott. Co., 1923. 1141 pp., illus., diagrs., tables, 8 x 5 in., fabrikoid $10.00.

This new edition, following the first after but three years, has been thoroughly revised and brought up to date. It contains tables, technical data and general information on the industrial utilization of petroleum products for all purposes except for fuel and also of the common fatty oils. The book covers a wide field and will prove useful to many classes of readers.

ELEMENTS OF ENGINEERING THERMODYNAMICS.

By James A. Moyer, James P. Calderwood and Andrew A. Potter. 2d edition. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. 224 pp., diagrs., 9 x 6 in., cloth. $2.50.

This book is intended to present the fundamental principles of the subject in a form suitable for use in technical colleges where special courses are given on the various applications of thermodynamics, such as steam turbines, internal combustion engines and refrigeration. The second edition has been thoroughly revised, in the light of experience, in order to make it more easily understood by the student.

ELEKTRONEN UND IONEN-STROME.

Br. Dr. J. Zenneck. Berlin, Julius Springer, 1923. 48 pp., illus., diagrs., 9 x 6 in., paper. .35.

Dr. Zenneck's lecture deals with recent developments in physics and is especially intended to demonstrate, by experiment the fact that every flow of electricity, independently of the medium in which it occurs, consists of a mechanical movement of electrically-charged particles.

A B C OF ATOMS.

By Bertrand Russell. N. Y., E. P. Dutton & Co., 1923. 162 pp., 8 x 5 in., cloth. $2.00.

Mr. Russell has set for himself the task of explaining, in non-technical language, what is known about the structure of atoms and how it has been discovered, so far as this is possible, without introducing any mathematical or other difficulties. He tells how atoms are studied and measured, gives the most recent theories of their structure and treats of the quantum theory, relativity, radioactivity and the new physics.

A. S. T. M. TENTATIVE STANDARDS, 1923.

By American Society for Testing Materials. Phila., The Society, 1923. 859 pp., illus., diagrs., tables, 9 x 6 in., cloth. $8.00.

The 1923 issue of this annual contains 190 tentative standard specifications and methods. These methods are published for the purpose of eliciting criticism before they are presented for adoption as standards by the Society. The specifications included relate to ferrous and non-ferrous metals; cement, lime, and clay products; preservative coatings; petroleum products; lubricants; road materials; coal; coke; timber; waterproofing; insulants; shipping containers; rubber products; textiles; thermometers. Tentative revisions of 42 present standards are also given.

AREAS AND VOLUMES.

By D. F. Ferguson & H. E. Piggott. N. Y., E. P. Dutton & Co., (1923). 88 pp., diagrs., 8 x 5 in., cloth. $1.60.

As mathematics is now taught, the pupil learns at an early stage many facts which he accepts as intuitive or else as laid down by authority, but without being very clear as to the chain of reasoning which may connect these facts. Then comes a later stage when these facts should be gathered into groups and the logical connection between the members of each group worked out.

The facts of the mensuration of areas and solids are learnt, some from arithmetic books, some from geometry, others from trigonometry. The object of this little book is to bring together these facts, to hang them on a logical chain, and to deduce some consequences. Approximate methods, which require no knowledge of calculus, are given particular attention.

ATOMES ET ELECTRONS; RAPPORTS ET DISCUSSIONS DU CONSEIL DE PHYSIQUE. Bruxelles, Avril 1921.

Institut International de Physique Solvay. Paris, Gauthier-Villars et Cie., 1923. 271 pp., 10 x 6 in., paper. 20 frs.

The Solvay Institute periodically brings together a Council of Physics, a sort of international congress composed of a small number of individuals, which meets at Brussels. The present volume contains the proceedings of the 1921 council, which was devoted to the question of atoms and electrons.

Among the papers included are: Notes on the theory of atoms, by H. A. Lorentz; the Structure of atoms, by Ernest Rutherford; on the Absorption of radiation by quanta in metals and the arrangement and movements of electrons in atoms, by R. A. Millikan; Paramagnetism at low temperatures, and Supra-conductors and the Rutherford-Bohr model of the atom, by H. Kamerlingh Onnes; the Application of the quanta theory to atomic problems, by N. Bohr.

CAR LIGHTING BY ELECTRICITY.

By Charles W. T. Stuart. N. Y., Simmons-Boardman Publishing Co., 1923. 356 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.00.

The almost complete supersession of oil and gas by electricity has created a need for a practical discussion of electric car-lighting equipment, written in language intelligible to laymen and covering its construction, operation, inspection and maintenance. This book attempts to fill this want. The three general systems of electric lighting are explained; the methods of operation inspection and maintenance are described at length. Full details of the leading five American systems of axle-generator equipment are given.

CONSTITUTION OF MATTER.

By Max Born. Translated from the 2d German edition by E. W. Blair, and T. S. Wheeler, N. Y., E. P. Dutton & Co., 1923. 80 pp., illus., diagrs., 9 x 6 in., cloth. $2.50.

Contents: The atom.—From mechanical ether to electrical matter.—Fusion of chemistry and physics.

The three essays which are published in this work appeared originally in "Die Wissenschaften." They deal with one subject, the physical theory of atoms, from different points of view; the first giving a general survey of the modern theory, while the

other two discuss questions which the author has himself endeavored to answer. The book is a useful summary for those who have not time to read the larger works on the subject.

Continuous-Current Circuits and Machinery, vol. 1.

By John H. Morecroft and F. W. Hehre. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. 467 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

The authors, who are respectively Professor and Assistant Professor of electrical engineering at Columbia University, have designed this book primarily for students in engineering schools. It covers the field in a manner suited to the average engineering student, and presents the subject so that the ordinary college course in physics is an adequate preparation.

Cours Complet de Mathematiques Speciales, vol. 4; Geometrie Descriptive et Trigonometrie.

By J. Haag. Paris, Gauthier-Villars et Cie, 1923. 2 vols., 10 x 6 in., paper. vol. 1, 13 fr. vol. 2, 15 fr.

The treatise, of which these volumes form the conclusion is designed as an intermediate text for students in search of a thorough grounding in fundamentals, as a step toward higher studies. The present section treats of descriptive geometry and trigonometry. The book is noteworthy for its clearness and great condensation. The author in general follows the program of the Ecole Polytechnique. The text is accompanied by many exercises.

Design of Diagrams for Engineering Formulas and the Theory of Nomography.

By Laurence I. Hewes and Herbert L. Seward. N. Y., McGraw-Hill Book Co., 1923. 111 pp., diagrs., 12 x 9 in., cloth. $5.00.

Contents: Function scales.—Elementary diagrams.—Alignment diagrams or collinear monograms.—Alignment diagrams for formulas in more than three variables.—Alignment diagrams with two or more indices.—Alignment diagrams with adjustment.—Apx. A, Determinants of the third order.—Apx. B, The projective transformation.—Index.

The usefulness of a diagrammatic solution of a formula is being increasingly recognized, and in this volume the authors have attempted to present in a practical way the principles of the design of diagrams or nomograms for the solution of engineering and other formulas. As the usefulness of diagrammatic solutions is in proportion to the resistance of the formula to calculation, the book does not merely give elementary methods of drawing simple diagrams but also aims to develop the grasp of the reader so that he will be able to analyze the more complex formulas of engineering. Fifty-four illustrative examples are given, which include many charts of general usefulness to engineers.

Electricity and its Application to Automotive Vehicles.

By Paul M. Stone. N. Y., D. Van Nostrand Co., 1923. 844 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

This book gives a systematic account of the electrical equipment of automobiles. Starting with the elementary principles of electricity, it takes up successively primary cells, storage batteries, measuring instruments, battery ignition, magnetos, spark plugs, generators, electric motors, gear shifts and protective and controlling devices. Following this are chapters devoted to the details of the various systems used on American automobiles. Information is given on the location and removal of troubles and on methods of operation.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—C. C. Cobb, 209 W. 2nd St., Oklahoma City, Okla.
2.—Mal L. Dodson, 1514 Van Buren St., Wilmington, Del.
3.—Charles E. Grant, Christie St. Hospital, Toronto, Ont., Can.
4.—Arthur S. Howard, 104 ½ West 10th St., Wilmington, Del.
5.—Robert J. Latorre, 157 Henry St., Brooklyn, N. Y.
6.—Donald T. Mason, 91 Wick Place, Youngstown, Ohio.
7.—Milan S. Mitrovitch, Box 254, Roseville, Placer Co., Calif.
8.—Albert A. Partoes, Compania Mallorquina de Electricidad, Palma, Balears, Spain.
9.—Otto Pramm, Hydro-Elec. Pr. Comm., Toronto, Ont.
10.—Wm. B. Schwartz, Apt. 1, 230 E. Fourth St., Atlanta, Ga.
11.—William J. Shannon, 1349 Fulton St., Brooklyn, N. Y.

Past Section and Branch Meetings

SECTION

Atlanta.—November 27, 1923. Subject: "Physical Construction of Grounds." Speaker: H. M. Towne, of the General Electric Co., Discussion followed the talk. Attendance 30.

Akron.—Subject: "Economic Features of the Development of Electric Power Interconnections for the District." Speaker: L. B. Tighe, Superintendent of Production and Distribution, Northern Ohio Traction & Light Co. Attendance 24.

Boston.—October 30, 1923. Subject: "Theory of Vacuum Tubes." Speaker: M. J. Kelly, of the Western Electric Company. A tribute was paid Dr. Steinmetz at the close of the meeting. Attendance 150.

November 22, 1923. Subject: "Industrial Research." Speaker: C. E. Skinner, Asst. Director of Engineering, Westinghouse Electric & Mfg. Co. Attendance 60.

December 11, 1923. Subject: "Common Sense and Mathematics in Engineering." Speaker: R. E. Doherty, Consulting Engineer, General Electric Co. Attendance 60.

Cleveland.—November 22, 1923. Subject: "Electrification of Steam Railways." Speaker: A. H. Armstrong, of the General Electric Company. Attendance 102.

Columbus.—November 23, 1923. A resolution upon the death of Dr. Chas. P. Steinmetz was adopted and spread upon the minutes. R. C. Bohannon, of the Erner and Hopkins Co., spoke on "Common Sense Radio Receivers." Prior to the meeting a motion picture "The Audion" was shown. Attendance 111.

Connecticut.—November 22, 1923. The meeting was held at Hartford, at the auditorium of the Hartford Electric Light Co. Subject: "Engineering Insurance." Speaker: W. R. C. Corson, Vice President, Hartford Steam Boiler Inspection and Insurance Co. Discussion followed. Attendance 150.

Detroit-Ann Arbor.—December 7, 1923. Subject: "Relativity." Speaker: Vladimir Karapetoff, Professor of Electrical Engineering at Cornell University. Attendance 400.

Erie.—November 20, 1923. Subject: "Modern Lighting." Speaker: C. E. Weitz, National Lamp Works, General Electric Co. Attendance 50.

Fort Wayne.—November 22, 1923. Subject: "Development and Construction of Water Softeners." Speakers: Carl Nordell, W. J. Hughes, E. J. Gallmeyer, all of the Water Softener Division, Wayne Tank Co. Attendance 106.

Indianapolis LaFayette.—November 23, 1923. Subject: "Astronomy." Speaker: Prof. W. A. Cogshall, of the Astronomy Dept., University of Indiana. Attendance 70.

Kansas City.—November 30, 1923. Subject: "High-Tension Construction," Speaker: L. O. Ripley, Vice-President of the Kansas Gas & Electric Co. Three reels of films were shown to illustrate the talk. Attendance 59.

Los Angeles.—October 30, 1923. The chairman reviewed some important points brought up at the Annual Convention of the A.I.E.E. A tribute to Dr. C. P. Steinmetz was paid before the subject of the evening was discussed. Subjects: "4400-Volt Isolated Delta Distribution," by L. B. Williams, of the Bureau of Power & Light, City of Los Angeles, and "Reasons for the Adoption of the 4000-Volt Grounded "Y" Type of Distribution by the Edison Company," by N. B. Hinson of the Southern California Edison Co. Attendance 67.

November 27, 1923. Subject: "Problems Encountered in Developing the 220,000-Volt Transmission Systems." Speaker: W. W. Lewis, Transmission Engineer, of the General Electric Company. Attendance 58.

Lynn.—November 21, 1923. The meeting was held in the General Electric Company hall, West Lynn. Subject: "Piezo Electric Effect in Quartz Crystals and Applications as Wave Length Standards." Speaker: G. W. Pierce, of Harvard University. Attendance 150.

November 27, 1923. Subject: "The Milky Way." Speaker: Dr. Harlow Shapley. Attendance 355.

December 8, 1923. Inspection trip to the laboratories of the Massachusetts Institute of Technology, Cambridge, Mass. Attendance 123.

Madison.—November 22, 1923. Subject: "Electrical Photometry of Stars." Speaker: Dr. Joel Stebbins, of the University of Wisconsin. Attendance 40.

Mexico City.—October 4, 1923. This was a business meeting at which matters of interest to this section were discussed. Attendance 14.

November 8, 1923. Business meeting. Attendance 22.

Minnesota.—November 26, 1923. Subject: "Astronomy." Speaker: Prof. Francis P. Leavenworth, University of Minnesota. Attendance 96.

New York Section.—On the evening of Wednesday, January 9, 1923, a meeting of the New York Section of the Institute will be held jointly with the Metropolitan Sections of the A. S. M. E. and A. S. C. E. Two papers will be presented, the first, "Electrical Systems of Greater New York", by Philip Torchio, Chief Electrical Engineer, New York Edison Company. The second paper entitled, "The Public Service Electric Company's System of Generation and Transmission in New Jersey", will be presented by R. N. Conwell, Transmission Engineer, Public Service Electric Co. of N. J. Following the presentation of the two papers ample opportunity will be given for discussion in which several engineers of prominence have promised to take part. Meeting to be held in the Auditorium, Engineering Societies Bldg., 33 West 39th St., New York, at 8 p.m.

Other meetings now scheduled: February 27—Jointly with A. S. M. E. and A. S. C. E., on a power subject; March 19—Jointly with A. S. M. E. and A. S. C. E., "City Planning and Transportation"; April 16—"The Telephone Systems of Greater New York"; May 21—Subject to be announced.

Philadelphia.—November 11, 1923. Subject: "Design and Operation of 13,200-Volt Induction Regulators." Speakers: Messrs. Smith and Lehr. Discussion followed by R. E. Funk. Attendance 125.

Pittsfield.—November 15, 1923. Subject: "Inventions and Patents." Speaker: A. A. Buck, Asst. Manager, Patent Dept., General Electric Co. Attendance 150.

November 22, 1923. Subject: "The Influence of Modern Naval Weapons on International Relations." Speaker: Rear Admiral W. S. Sims, U.S.N. Attendance 750.

December 7, 1923. Subject: "Big Creek in the High Sierras." Speaker: David H. Redinger, Resident Engineer, Big Creek Development, Southern California Edison Co. Attendance 325.

Portland.—November 14, 1923. There was a general discussion by a number of engineers of the Portland Railway, Light & Power Co. of the Oak Grove Hydroelectric Development. Lantern slides illustrated the lecture. Attendance 130.

November 27, 1923. A series of talks were given by six local section members, welcoming the visiting students from Oregon Agricultural College, and three inspection trips were planned for them. Attendance 80.

Providence.—November 22, 1923. Subject: "Electric Welding", Speaker: Comfort A. Adams, Professor of Electrical Engineering, Harvard University and Past President of the Institute.

Rochester.—December 7, 1923. Subject: "The Romance of Niagara Falls." Speaker: George S. Anderson, Publicity Director of the Niagara Falls Power Co. The address was accompanied by stereopticon views. Attendance 45.

San Francisco.—October 26, 1923. Subject: "Public Utility Regulations." Speaker: Clyde L. Seavey, President, California State Railroad Commission. Attendance 80.

November 27, 1923. Subject: "Radio Communication," Speaker: E. F. W. Alexanderson. Admiral Bullard, former chief of the Radio Communication Dept. of the U. S. Navy, was present and presented a very interesting contribution to the discussion in the form of the early history of radio communication in this country. Attendance 150.

Schenectady.—November 16, 1923. Subject: "Decorative Art as Applied to Modern Manufacture." Speaker: J. W. Gosling. Attendance 120.

December 7, 1923. Subject: "Recent Development of the Adirondack Power and Light Corp." Engineers of the Adirondack Power and Light Company discussed the following phases of the subject: Development of the System, by Otto Snyder; Two Recent Hydroelectric Developments, Sprite Creek and Bearsdlee Falls; Types of Outdoor Substations, by C. A. Bacon, and the New Amsterdam Steam Station, by W. A. Shoudy. Lantern slides illustrated the talks. Attendance 275.

St. Louis.—November 5, 1923. This was a memorial meeting in honor of Dr. Charles P. Steinmetz, and was a joint meeting in connection with the St. Louis Electrical Board of Trade. Prof. E. J. Berg, of Union College, Schenectady, N. Y. gave a talk about his personal association and acquaintance with Dr. Steinmetz. Attendance 60.

Seattle.—November 15, 1923. Business meeting and tribute to Dr. Steinmetz preceded the presentation of the paper: "High Efficiency Currents." Speaker: H. T. Plumb, of Salt Lake City, the present Vice-president of District No. 9. Lantern slides and chalk talks illustrated the lecture. Attendance 58.

November 22, 1923. Subject: "Problems in Designing and Location of Receiving Stations." Speaker: E. F. W. Alexanderson, Chief Engineer, Radio Corporation of America. Discussion followed by Dr. Magnusson, Mr. Tolmie and others. Attendance 180.

Spokane.—October 29, 1923. R. L. Hearn and L. J. Pospisil gave an illustrated talk on some of the recent California developments which they had visited. Atendance 30.

Springfield.—October 26, 1923. Subject: "Scope of Discovery, Invention, Research and Development Pertaining to the Electrical Industry." Speaker: C. A. Skinner. Attendance 70.

November 27,1923. Subject: "The Handling of Telephone Traffic in a Machine Switching System". Speaker: Wm. E. Farnham, Traffic Engineer of the American Tel. & Tel. Co. Discussion followed. Attendance 75.

Syracuse.—November 26, 1923. Subject: "The Romance of Niagara." Speaker: G. S. Anderson, Director of Publicity, Niagara Falls Power Co. Attendance 150.

Toronto.—November 16, 1923. Subject: "Measurement and Automatic Control of Temperature." Speaker: Robert Whipple, Scientific Director of the Cambridge and Paul Instrument Co. Considerable discussion followed and a vote of thanks was given the speaker. Attendance 67.

Vancouver.—November 16, 1923. Subject: "Engineering and Education." Speaker: H. T. Plumb, Vice-President, District 9. A short talk about Dr. Steinmetz preceded the presentation of the paper. Attendance 19.

Washington.—November 13, 1923. Subject: "Standardization in Industry." Speaker: C. E. Skinner, Assistant Director of Engineering, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Attendance 137.

Worcester.—November 22, 1923. Subject: "Operating Characteristics of Alternating and Direct-Current Motors." Speaker: F. S. Dellenbaugh, Jr., Secretary of the Electrical Research Division, Massachusetts Institute of Technology. Attendance 50.

BRANCH

Alabama Polytechnic Institute.—November 14, 1923. A business meeting preceded a talk by C. W. Cooper of the Westinghouse Electric & Mfg. Co. on working conditions with that company. Attendance 22.

University of Arkansas.—November 14, 1923. The following papers were presented: "Oil Refining," by R. T. Purdy, "Telephone Transmission over Long Distances," by D. D. Ault, and "Indirect Lighting and Some of Its Applications," by C. E. Bowman. Lantern slides loaned by the National X-ray Company were shown. Attendance 17.

Armour Institute.—November 15, 1923. Business meeting. Attendance 16.

December 7, 1923. Business meeting and talk by a student, Mr. Almendinger, on "Automatic Train Control." Attendance 19.

University of California.—November 21, 1923. Subject: "Electrolysis." Speaker: R. H. Bennett, of the Pacific Telephone and Telegraph Co. Attendance 42.

December 5, 1923. Nomination of officers was made, and a social meeting followed. Attendance 47.

Carnegie Institute of Technology.—December 6, 1923. Subject: "Modern Transmission Problems." Speaker: A. N. Cartwright, Chief Engineer of Transmission, West Penn Power Co. Discussion followed. Attendance 50.

Case School of Applied Science.—November 2, 1923. Talks on the advantages of membership in the A.I.E.E. and other subjects interesting to young engineers were made by Mr. George Mills, Mr. T. D. Owens, Mr. Wertz, all of the faculty, and Mr. Harry Wills, Alumni Secretary, Attendance 31.

University of Cincinnati.—November 1, 1923. This was a joint meeting of all the local technical student branches, at which a moving picture "Flying at McCook's Field" was shown. Attendance 144.

November 8, 1923. Repetition of the moving picture shown at the November 1st meeting. Attendance 125.

November 15, 1923. There was a talk by Mr. O. F. Shepard, President of the Shepard Elevator Co., urging an inquiring attitude of mind in engineering students. Attendance 33.

Clemson.—November 23, 1923. Reviews of papers published in the A.I.E.E. Journal were given by students as follows: "Pellet Type of Oxide Film Lightning Arrester," by C. M. Asbill, and "Facts About Priest Rapids", by S. I. Bell, and "A Continuous-current Generator for High Voltage," by J. H. Sims. Attendance 22.

December 6, 1923. Papers pertaining to electrical applications in the iron and steel industry were discussed as follows: "Iron and Steel," W. H. Moore; "Motorizing the Homestead Steel Works," by J. H. Sims and "The Reliability of Power in the Steel Industry," by G. M. Speer. Attendance 19.

Colorado Agricultural College.—October 16, 1923. Subjects: "Charging Capacity of High-Voltage Line Towers in California," by Mr. Truesdale, and "Electric Locomotives of C. M. & St. P. Railway." Attendance 18.

October 29, 1923. Business meeting. Attendance 12.

University of Colorado.—November 14, 1923. The following students spoke on: "Report on Denver Section Meeting," by R. D. McWha; "Moss Superchargers on Liberty Motors," by H. Newman; and "Armature Winding at the Colorado Fuel & Iron Company," by E. Fabrizio. Attendance 40.

November 27, 1923. Subject: "Railway Electrification in the United States." Speaker: H. B. Barnes, of Denver, Colo. The talk was illustrated with slides. Attendance 50.

Denver.—December 7, 1923. Engineering students of the whole university were invited to attend this meeting, at which Mr. H. B. Barnes, Ex-Chairman of the Denver Section, spoke on "Electrification of Railroads."

Detroit-Ann Arbor.—November 13, 1923. Subject: "Radiation, the Relation between Matter and Light." Speaker: Dr. Wheeler P. Davey, of the General Electric Co. Attendance 205.

Drexel Institute.—November 17, 1923. A business meeting preceded the presentation of the following papers: "The New P.R.T. Trackless Trolleys," by C. L. Shock; "Individual Motor Drive for Cotton Mills," by T. C. Wang; "Light and Illumination," by David L. Michelson; "Training of an Electrical Engineer," by Prof. Robert C. Disque. Attendance 48.

December 7, 1923. This meeting was thrown open to the public. Dr. Majiski, Chief Consulting Engineer on the Delaware River bridge, spoke on "The General Construction of the Largest Suspension Bridge in the World". The lecture was illustrated with slides. Attendance 338.

State University of Iowa.—October 15, 1923. Subjects: "Testing Watthour Meters", by C. O. Sloan; and "Making a Survey of Power and Light Co. of Cedar Rapids," by J. R. Eyre. Attendance 49.

October 22, 1923. Subjects: "The Carbon Circuit Breaker," by E. G. Blythe; "Direct-Connected Induction Motors Versus Geared Motors for Use in Steel Mills," by H. W. Bowen; "Reliance Type AA Induction Motor," by John Brauns. Attendance 47.

October 26, 1923. Joint meeting with local branches of the A.S.M.E., and A.S.C.E. An addres was made by W. S. Murray, consulting engineer of New York City on "Superpower." Attendance 50.

November 5, 1923. Subjects: "Some Recent Developments in Vacuum Tubes for Radio Reception," by J. M. Dean; "Electrical Development in Australia," by H. E. Fetig; and "Manufacture of Telephone Cable in Western Electric Company's Plant," by H. L. Gerard.

November 26, 1923. The following papers were given: "Storage Batteries," by Geo. C. K. Johnson; "The Automatic Network Protector," by A. Krehbiel; and "Wind-Driven Generating Plants," by H. F. Olson. Attendance 48.

December 3, 1923. This was a joint meeting with the A.S.M.E. and A.S.C.E. student branches. Prof. Woodward, of the Dept. of Civil Engineering delivered an illustrated address on "Flood Prevention in the Vicinity of Dayton, Ohio." Attendance about 100.

Kansas State College.—November 12, 1923. Subjects: "Hydroelectric Power Generation at Idaho Light & Power Co.," by A. B. Haines, and "The Empire Gas and Fuel Co.", by C. K. Gibbon. Attendance 52.

University of Kentucky.—November 9, 1923. Subject: "The Colfax Power Station," by Prof. A. E. Bureau. Attendance 23.

Lafayette College.—October 27, 1923. Subject: "Transmission," Speaker: W. E. Lloyd, Jr., Supt. of Transmission for the Pennsylvania Power & Light Company. Attendance 19.

November 17, 1923. Prof. King gave a short talk on the construction of Sangamo ammeters and watt meters, followed by a moving picture of the construction.

November 24, 1923. Visit to the Phillipsburg Reswitching Station of the Pennsylvania Edison Co.

Marquette University.—November 15, 1923. Business meeting, followed by a talk on "Electrical Machinery for Long

Transmission Lines," by Herbert Suhr. Discusion ensued. Attendance 38.

Massachusetts Institute of Technology.—November 14, 1923. This meeting was a smoker at which A. H. Northrup, of Stone & Webster, Inc., spoke on "Hydroelectric Developments." A motion picture of the Caribou development was shown.

November 26, 1923. Inspection trip through the New Aspinwall Full Mechanical Exchange of the Boston Telephone Co.

Michigan Agricultural College.—Business and social meeting. Attendance 25.

University of Michigan.—October 15, 1923. Announcement of election of officers as follows: Chairman, C. C. Varnum; Vice-Chairman, K. V. Tang; Treasurer, P. N. Young. Attendance 25.

November 26, 1923. Business meeting.

School of Engineering, Milwaukee.—November 22, 1923. Subject: "The Advantages of Being a Member of the Institute." Speaker: F. A. Vaughn. Attendance 40.

University of Minnesota.—November 13, 1923. Subjects: "Principles and Purposes of the A.I.E.E.," by Prof. W.T. Ryan; "The A.I.E.E. in Student Life," by Mr. Roy Olson; and "Development of Engineering at Minnesota," by Prof. G. D. Shephardson. Attendance 45.

Montana State College.—December 4, 1923. A group of juniors discussed the subject "Batteries and Applications of Storage Batteries." Attendance 99.

November 27, 1923. A group of seniors presented a paper on "Railway Electrification." Attendance 98.

University of Nebraska.—December 6, 1923. Edwin Bartunek, F. G. Henneman and Harry Hays spoke on their summer work with the Western Electric Company and Commonwealth Edison Company in Chicago. Attendance 30.

University of Nevada.—November 14, 1923. Subject: "History and Development of Watthour Meters." Speaker: John Bridges, Meter Specialist, Westinghouse Electric & Mfg. Co., San Francisco, Cal. Attendance 49.

University of North Carolina.—November 25, 1923. Three motion pictures loaned by the General Electric Company were shown. Attendance 52.

University of North Dakota.—November 26, 1923. Subject: "The Electric Storage Battery." Speaker: P. G. Downton, Manager of the Minneapolis Branch of the Electric Storage Battery Co. Attendance 38.

December 10, 1923. Subjects: "The Automatic Telephone," by T. E. Lee and "The Advance of the Electrical Engineering Industry," by Mr. Thorleifson. Attendance 16.

Notre Dame University.—November 19, 1923. Business meeting, and demonstration of transformer action in coils was given by Kenneth Faiver. Attendance 48.

December 3, 1923. Subjects: "Storage Batteries," by Frank Meagher and "The Electron Flow in Electron Tubes," by Kenneth Faiver. Attendance 36.

Ohio Northern University.—November 15, 1923. Election of officers as follows: Chairman, Arthur Upp; Vice Chairman, Dale Carpenter. Subject: "Vacuum Tubes," by Mr. Shafer. Attendance 36.

Ohio State University.—November 30, 1923. Subject: "The Electron." Speaker: Prof. Vladimir Karapetoff, of Cornell University. Attendance 250.

University of Oklahoma.—November 22, 1923. Subjects: "Radio Vacuum Tubes," by M. L. Prescott and "The Opportunities in the Numerous Branches of Electrical Engineering for Engineers," by Prof. Page. Attendance 22.

University of Pennsylvania.—December 11, 1923. Subject: "Supervisory Control of Automatic Substation Apparatus," by Mr. Wensley, of the Westinghouse Electric & Mfg. Co. Attendance 84.

Pennsylvania State University.—December 4, 1923. Business meeting followed by a talk by N. S. Hibshman, a student, on his research work with X-rays and electrons. Attendance 23.

Polytechnic Institute of Brooklyn.—November 9, 1923. Subject: "High Power Radio Transmitting Tubes," by W. G. Houskeeper, of the Western Electric Company. Discussion followed. Attendance 59.

Purdue University.—November 13, 1923. A two-reel educational film on the "Wizardry of Wireless," was presented by Prof. R. V. Achatz and L. W. Franklin. Attendance 133.

November 27, 1923. Subject: "Early Engineering Experiences in England." Speaker: Prof. Alfred Still. Attendance 60.

Rensselaer Polytechnic Institute.—November 19, 1923. Subject: "Superpower," by W. S. Murray, Consulting Engineer, of New York City. Attendance 336.

Rutgers College.—November 22, 1923. Business meeting followed by papers: "Control of Motors," by W. F. Scott; "Coal Problem and a Solution," by J. C. Neary; "Features of the Hellgate Power Plant," by C. G. Riley. Attendance 17.

University of California.—November 7, 1923. Subject: "Transformers." Speaker: W. C. Smith, of the General Electric Co. Attendance 41.

University of Maine.—November 16, 1923. Talks were given by Mr. Saunders on his experiences last summer at the General Electric Company's plant at Schenectady and Prof. W. E. Barrows on the history and development of the electrical industry. Attendance 15.

University of Southern California.—November 14, 1923. Inspection trip to the Laguna Bell 220,000 volt substation of the Southern California Edison Co. Attendance 45.

Stanford University.—November 13, 1923. "Experiences in Power Plant Operation." Speaker: Ward B. Kindy. Attendance 11.

November 25, 1923. Business meeting. Attendance 7.

Swarthmore College.—November 9, 1923. There was a talk by Howard Davis, a student, on his summer's work with the Philadelphia Electric Company with particular reference to testing of meters. Attendance 10.

November 16, 1923. Subjects: "Manufacture of Bearings, and Their Relation to Dynamos and Other Electrical Machinery and Devices," by Thomas Parris. Attendance 9.

State College of Washington.—November 13, 1923. Subject: "Why We Study Engineering in College," by Lloyd Brown and "Street Cars," by Philip Friedlund. Attendance 35.

A. & M. College of Texas.—November 16, 1923. A talk on the life of Dr. Steinmetz was made by Mr. Ashburn, a student. R. P. Ward talked on the electric power industry in California. Social hour followed. Attendance 84.

November 2, 1923. Election of officers as follows: President, R. L. Garrett; Secretary, A. A. Ward. F. C. Bolton, Dean of the School of Engineering, gave a talk on the aims and purposes of the branch. Attendance 63.

December 7, 1923. The following talks were given: "The Moore Tube," by Mr. Scheuneman; "History of Electromotive Power," by Mr. Halecamp. Attendance 60.

Virginia Military Institute.—September 20, 1923. Election and installation of officers as follows: Chairman, J. M. Yates; Secretary, J. B. Lacey, Jr. Attendance 26.

October 22, 1923. Subjects: "Aim of the A.I.E.E.," by J. M. Yates; "The Heat Balance in a Modern Power Plant," by R. K. Waring. Attendance 25.

Virginia Polytechnic Institute.—December 6, 1923. Subject: "The Manufacture of Incandescent Lamps," by A. E. Snyder, Asst. Commercial Engineer of the Westinghouse Electric & Mfg. Co. Attendance 44.

University of Washington.—December 4, 1923. Subject: ',The Caribou Hydroelectric Project," by L. N. Richardson, Vesident Engineer of the Seattle office of Stone & Webster, Inc. Rttendance 35.

Washington University.—November 23, 1923. Inspection trip of the entire branch membership to the power plant of the Union Electric Light and Power Co. now under construction at Gahokia, Ill. Attendance 75.

December 4, 1923. Subject: "Electrical Engineering Phases of the Recent $81,000,000 Bond Issue," by R. T. Toensfeldt, Chief Electrical Engineer of the Dept. of Public Utilities of St. Louis, Mo. A motion picture loaned by the General Electric company, "The Wizardry of Wireless" was shown. Attendance 43.

West Virginia University.—November 19, 1923. The following papers were given: "Drying of Transformers," by Mr. Davis; "Automatic Operation of Telephones," by Mr. Barone; "Voltages Induced by Arcing Grounds," by Mr. Brown; "Power Transmission at High Voltages," by Mr. Witt; "Change from Overhead to Underground Installation," by Mr. Worden; "Filter-Press Type of Dehydrator," by Mr. McCullough; "Life of Faraday," by Mr. West; "Life of Steinmetz," by Mr. Rousch; "Motor Fuel from Coal," by Mr. Mountain; "Application of Light Weight Double Truck Cars," by Mr. Robinson; "Residence Heating by Electricity," by Mr. De Veebre; "Inspection of Alternators," by Mr. Kellerman. Attendance 33.

University of Wisconsin.—December 5, 1923. Subject: "The Undergraduate and the Engineering Field," by John N. Cadby, Executive Secretary of Wisconsin Utilities Association. Attendance 30.

November 14, 1923. Business meeting. Attendance 33.

PERSONAL MENTION

Ernest Axman has recently taken a position as Instructor at the Pennsylvania State College, State College, Pa.

Dana Pierce was elected President of the Underwriter's Laboratories, Chicago, Ill., at a special meetirg of the board held on November 10th.

H. W. James has severed his connection with the Hudson Coal Co. as Electrical Engineer, and entered the consulting field with offices in Scranton, Pa.

G. T. Seely has formed a connection with the Yellow Coach Mfg. Co., Chicago, Ill. He was formerly with the Mahoning & Shenango Ry. & Light Co., Youngstown, Ohio.

Thomas B. Everist, formerly with the Leeds and Northrup Company has accepted a position as Supervisor of Radio Production with the Boonton Rubber Mfg. Co., Boonton, N. J.

M. W. Manz, who has been until recently with the Ohio Insulator Co., has accepted the position of Director of Development Engineering, Ohio Brass Company, Mansfield, Ohio.

Howard C. Miller has resigned as Electrical Construction Engineer for the Eastern Oregon Light & Power Co. to accept a position with the Washington Pulp and Paper Company of Washington.

L. R. Woodcock, who has until recently been in the employ of the Parklap Construction Corp., Glens Falls, N. Y., has resigned to become Assistant to Mr. Forbes, Chief Electrical Engineer to the Nysore Government, Bangalore, Nysore, India.

Rawson Collier, formerly Sales Manager of the Central Hudson Gas & Electric Company, Poughkeepsie, N. Y., has joined the forces of Dwight P. Robinson & Co., Inc., New York City, and opened Southern offices for this firm on December 1st at Atlanta, Ga.

Thomas Q. Morton, formerly Superintendent of Light, Heat and Power at Prairie View, Texas State College and recently Supervising Power Plant Engineer at Tuskegee Institute, Tuskegee, Ala., is now Professor of Physics at West Virginia College, Institute, W. Va.

F. B. Jewett, Vice President of the Western Electric Company, has been decorated with the fourth class of the Imperial Order of the Rising Sun by the Emperor of Japan. Notice of the honor has come directly from Sannosuke Inada, Chief Engineer of the Japanese Department of Communications.

William Porter White has been appointed to act as personal assistant to the new executive assistant manager of the Central Station Dept. of the General Electric Company, with headquarters in Schenectady, N. Y. He has recently been in charge of commercial engineering work in the Transformer Dept. at Pittsfield.

F. W. Peek, Jr., Consulting Engineer, General Electric Co., has been awarded the Thomas Fitch Rowland Prize for his paper on "High-Voltage Power Transmission". The presentation of this prize will take place on January 16, 1924, the first day of the 71st Annual Meeting of the American Society of Civil Engineers, New York, N. Y.

Elihu Thompson, a Past-President of the American Institute of Electrical Engineers, has recently been awarded the Kelvin Gold Medal, which is awarded trienially as a mark of distinction to a person who has reached high eminence as an engineer. The fund for this medal is administered by the Institution of Civil Engineers, and the Committee is composed of the presidents of the principal British engineering societies.

Obituary

John Mustard, who has been associated with the electrical industry almost from its inception, died on December 12th at his home in Philadelphia. He was born May 9, 1867, in Smyrna, Del. From 1884 to 1887 he was associated with the Marr Construction Company, Pittsburgh, Pa., being a pioneer in the installation of electric light plants. The following year he formed the contracting firm of Kingsbury & Mustard, Baltimore, Md., and in 1891 joined the Wagner Electric Manufacturing Company, St. Louis, as its Philadelphia representative. This position he held without interruption until the time of his death. He was a member of the Art Club, Manufacturers' Club, Electric Club, White Marsh Country Club and Associated Electrical Club of Philadelphia, and an Associate of the American Institute of Electrical Engineers.

Ralph E. Gilman, special engineer in charge of turbo-generator engineering of the Westinghouse Electric & Manufacturing Company, died in the Methodist Hospital, Los Angeles, December 5. Mr. Gilman, on account of illness, had been granted a leave of absence from his duties in East Pittsburgh, Pa., to go to the Coast in an effort to improve his health.

He was a graduate of the Leland Stanford University of Palo Alto, Cal., receiving his E. E. degree in 1898. He entered the employ of the Westinghouse Company immediately after his graduation and completed the apprentice course of the Company in January 1901. The next two years he was located in the engineering department. In 1903 he was transferred to the British Westinghouse Company and spent the next five years in London, England. In 1908, Mr. Gilman was recalled to East Pittsburgh and assigned to special duties in the power engineering department. He was in this department continuously until the time of his death. He became a Member of the Institute in 1920.

Employment Service

The Engineering Societies Employment Service is conducted by the national societies of Civil, Mining, Mechanical, and Electrical Engineers as a cooperative bureau available to their membership, and maintained by the joint contributions of the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Under this heading brief announcements will be published without charge to the members. These announcements will not be repeated, except upon request received after an interval of three months, during which period names and records will remain in the active files of the bureau. Employers are referred to previous issues of the Journal. Notice for the JOURNAL should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City.*** *Such notices will not be acknowledged by personal letter, but if received prior to the 16th of the month will usually appear in the issue of the following month.*

OPPORTUNITIES.—A bulletin of engineering positions available will be published and will be available to members of the societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the societies in the financing of the work by nominal contributions. It is believed that a successful service can be developed if these contributions average $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum. temporary positions (of one month or less), three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled, will not be forwarded.

POSITIONS OPEN

GRADUATE ENGINEER for life test and photometry of tungsten lamps. This experience desirable but not essential. 1920 or 21 graduates considered. Application by letter. Salary not stated. Location, Mass. R-2724.

MEN AVAILABLE

ELECTRICAL AND CIVIL ENGINEER with technical education and twenty-five years' experience in designing, constructing and operating hydroelectric and steam plants and in the high-tension transmission of power. Also executive experience as manager and organizer of properties. Available January 1st. E-4597.

ELECTRICAL AND MECHANICAL ENGINEER with fine technical and business training wishes larger field for efforts, management, sales or construction. Twenty years with present employer. Age 38; prefer west coast, but will consider any location. E-4598.

ELECTRICAL ENGINEER, Cornell graduate with experience in electrical communications, telephony, meter work, drafting; recent graduate; age 23; location in New York City. E-4599.

EXECUTIVE ENGINEER, age 37 years, graduate Cornell 1911, electrical manufacture shop course, public utility experience, industrial plant investigations, power plant design and operation, executive and general manager industrial plant. Services now available. E-4600.

ELECTRICAL CONSTRUCTION AND MAINTANANCE FOREMAN wishes position with some established manufacturing concern or public utility company. 11 years' experience; 3 years in service ship and on road; 3 years G. E. test. Technical education. Best of references; married; age 33. E-4601.

ELECTRICAL DISTRIBUTION ENGINEER, technical graduate; age 30, married. At present in charge of overhead and underground distribution for a New York public utility company and would prefer to continue along similar lines. Have also had several years' experience in mechanical and electrical test work in power plants. Available on short notice. E-4602.

ELECTRICAL ENGINEER, desires position as superintendent or manager of electrical utility property in city of 5000 to 10,000 population. Experience covers four years as superintendent of several southern cities, three years as assistant distribution engineer in one of the growing cities of Texas. Preference as to location North Central States or foreign. E-4603.

ELECTRICAL ENGINEER, technical graduate; age 35; married; with thirteen years' engineering, sales, commercial and executive experience, desires position with consulting firm, public utility company or industrial organization. Wide experience in public utility field. Now in business, but available after Jan. 1st. E-4604.

RECENT GRADUATE B. S. in electrical engineering; age 22; has had some experience in electrical power plant drafting, and also as electrician wiring for light and power, testing and repairing electrical machinery. Desires permanent position with power plant designing firm or concern doing electrical testing. Location immaterial. E-4605.

ENGINEER in charge industrial power division of consulting firm, desires central or southern location offering construction, operation or betterment work with manufacturing public, or consulting firm. Energetic, reliable and exceptionally well fitted by responsible charge of similar work with the most prominent companies. Two years' pulverized coal experience. E-4606.

ELECTRICAL ENGINEER, technical graduate; special work in mathematics; married; age 32; Captain during the war, in charge of officers schools. Recently passed second in civil service examination for highest position in state. Certificate for teaching electrical engineering and kindred subjects in high school. Now teaching electrical engineering and kindred subjects, on own time, to employees of large electrical corporation. Practical experience selling industrial equipment for Westinghouse; and building and maintaining distribution lines for large public utility. Available 30 days after agreement. E-4607.

ELECTRICAL ENGINEER, age 30; married; technical graduate; 4 years' experience in deisgn of steam power plants, transmission lines and electrical distribution systems; experience in appraisal of utility properties, factory management accounting, slip form concrete construction, and surveying. Desires position with public utility or as city manager in town of 15,000 population. Last salary $2400. Available immediately. E-4608.

ELECTRICAL AND ACOUSTICAL ENGINEER, Canadian; age 35; married; good health; B. A. Sc. Toronto 1911. Four years on development and research work in Royal Air Force, principally on original inventions. Co-inventor and at present completing the development of an electric recording system, using telephone apparatus. E-4609.

GRADUATE ELECTRICAL ENGINEER 1923, B. S. in E. E.; single, foreign born; speaks several languages; 3 years' experience in mechanical and electrical drafting and design; good knowledge of mathematics; desires position with electrical or radio concern where ability is recognized. E-4610.

ELECTRICAL ENGINEERING GRADUATE, Assoc. A. I. E. E., having had a year and nine month's experience in G. E. test and a year and six months' with public utility and manufacturing company in connection with indoor and outdoor substations and transmission; desires position in which there is opportunity for advancement. E-4611.

DEVELOPMENT ENGINEER, M. E. Cornell, Mem. A. I. E. E. Thirteen years investigation, design and manufacture with large and small organizations; six years installation, mostly for U. S. and foreign governments; five years sales. Experienced in telegraph, telephone and submarine apparatus and construction, cable in manufacturing and other heavy machinery, motor trucks and gas apparatus. Age 46; married; excellent health. E-4612.

MECHANICAL AND ELECTRICAL ENGINEER, age 38, graduate 4 years' course, with 20 years' experience in various electrical work, specialized on hydroelectric station, substation and transmission line design, formerly with large public utility in charge of engineering office, for the last six years and at present employed in general industrial work by large western mining and smelter interests. Desires responsible position as engineer with public utility corporation, manufacturing or mining company. Position must be permanent. Location immaterial. E-4613.

YOUNG ENGINEER, technical graduate 1922, with electrical design experience, desires change to work into hydroelectric plant, layout or installation, with public service company as consulting engineer. Employed at present, but available on 30 days' notice. E-4614.

ENGINEERING EXECUTIVE now directing research and engineering force of 50 in radio, cable and wire communication field; desires wider opportunity, preferably where a business interest in the organization can be purchased; age 39; married; graduate of M. I. T. in E. E., Mem. I. R. E., Assoc. A. I. E. E. Best references. Engaged in communication line 17 years with Government and Bell Company. Nothing but established business organizations considered. E-4615.

ELECTRICAL ENGINEER, five years' experience in distribution engineering with an electric light company; desires position with a public utility or manufacturing company. E-4616.

GRADUATE ELECTRICAL ENGINEER with 6 years' experience in United States and in

the Scandinavian countries; available for a leading position. E-4617.

ELECTRICAL ENGINEER, technical education and 24 years' experience on construction, installation and erection. Desires connection with reliable enterprise. West Va., Penn. preferred. Good record on handling men and big jobs. Salary commensurate with responsibility. E-4618.

ELECTRICAL AND MECHANICAL ENGINEER experienced in designing and construction of industrial and power plants, rehabilitation of old and inefficient plants. Good initiative and ability, excellent references. Desires position as chief electrician or assistant to chief engineer in paper mill or other large industry. Location preferably in middle or eastern states or Canada. E-4619.

TECHNICAL GRADUATE having B. Sc. in electrical engineering, age 24; single; Westinghouse graduate-student course. At present employed. Desires position with middle western public utility or with consulting engineers. Assoc. A. I. E. E. E-4620.

ELECTRICAL ENGINEER OR SUPT. ELECTRICAL CONSTRUCTION, age 34; technical education, G. E. Test; over 10 years' experience engineering and construction power plants and industrial plants of all kinds. E-4621.

ELECTRICAL ENGINEER, 44 years old; married; 12 years experience in design of steam and hydroelectric power plants; indoor and outdoor stations, up to 100,000 volt; rotary converter installations and illumination, desires position of some responsibility. Assoc. A. I. E. E. Available Jan. 1st, 1924. Location, U. S. E-4622.

ELECTRICAL ENGINEER, technical training; age 25; desires a position with reliable concern, E. E. graduate; 5 years' electrical construction and maintenance experience; 2 years city inspection, 1 year sales. Desires position with construction. Power or consulting engineer or sales. E-4623.

GRADUATE ELECTRICAL ENGINEER, age 24; single; Western Electric manufacturing course 5 months; 8 months in the meter testing and service department of a large utility. 6 months in the drafting department of a large public utility, substation design department. Employed at present. Desires position in engineering department. Location, middle west or west. E-4624.

ENGINEERING EXECUTIVE, American; age 38; with 18 years' experience in design and construction of power; substations and industrial plants, transmission and distribution systems, light, power and telephone layouts, fuel problems, electrolysis surveys, reports, specifications consultation. Reliable, energetic and capable of producing results efficiency. Mem. A. E. S., A. I. E. E. and I. R. E. Unquestionable references furnished. E-4625.

ELECTRICAL ENGINEER with considerable experience and successful record in development of intricate electro-mechanical problems. Has been accustomed to make a theoretical anaylsis, preliminary commercial survey and carrying out of experiments, design construction and patent routine. E. E. and M. E. degree. Highest credentials available. Fourteen years of practise here and abroad. Resident of New York City, married; 38. Minimum salary, $5000. E-4626.

SEARCH ENGINEER ten years of experience as research assistant and manager in development of electrical measuring instruments and their industrial applications. Well grounded on pyrometry, electrochemistry, magnetic measurements, photometry and automatic process control. Available after Jan. 15th, minimum salary $5000. Present location, Philadelphia, Pa. E-4627.

POWER PLANT ENGINEER, 27; experienced in steam and hydroelectric generation, maintenance, and construction desires position with company large enough to offer advancement in return for hard work. Active student on combustion and steam power economics, and has lately been in charge of plants having 50 operatives. Especially desires position where hard work and study will be recognized instead of long years of experience. Technical education: will go anywhere. E-4628.

SUPERINTENDENT OF LIGHT AND POWER DISTRIBUTION SYSTEM in charge of town of 3500 population in Canada is looking for a larger opportunity. Construction and maintenance past experience has been practical and thorough. Now serving as manager and superintendent. Assoc. A. I. E. E. E 4629.

ELECTRICAL ENGINEER M. I. T. 1918. Four years' experience on G. E. test, with power and engineering companies. Thoroughly familiar with electrical machinery, power plants, and transmission systems up to 150,000 volts. Experienced radio engineer. Desires position as assistant to an executive or in sales organization of electrical manufacturer. Open to teaching position. E-4630.

AN ELECTRICAL MAINTENANCE ENGINEER desires engagement by a mining paper or industrial company or as superintendent of a small utility. Fully competent to assume entire charge of your plant and operate it efficiently. 66,000-volt experience. A. I. E. E. Available immediately. E-4631.

ELECTROCHEMICAL ENGINEER, graduate of M. I. T., with six years of college work in physics, chemical engineering, electrical engineering, mathematics and engineering administration. Familiar with patent and technical literature. Has initiative, aggression and integrity. Desires permanent employment with a company which offers opportunity for advancement; age 26. An unusual man for a progressive company. E-4632.

ELECTRICAL ENGINEER, graduate Univ. of Mich. Assoc. A. I. E. E.; 10 years' experience covering construction, operation and maintenance of high-tension generating stations, indoor and outdoor substations and installations of factory equipment wishes a responsible position with construction engineer or light and power company. Location, U. S. A. or abroad. E-4633.

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING in educational institution. Several years' experience. Degrees from two Eastern Universities. Formerly instructor of electrical engineering. Lately assistant professor of physical and chemical science. Will consider printing or publishing book manuscript concerning alternating-current theory, experiments, and research. E-4634.

LICENSED PROFESSIONAL ENGINEER with electrical engineering as his specialty, having versatility in allied branches (mechanical, structural, concrete, etc.) available for engagement. Successful experience in power station work, design and development of various new machines (electrical and mechanical), research aided by theory and mathematics, resourceful, reliable, productive in office and field. E-4635.

WELDING ENGINEER, an executive and a recognized authority on welding who is capable of taking charge of, and developing to the fullest extent the possibilities of welding in all of its forms, in an industrial organization. Affiliation, as chief welding engineer, is desired with a large corporation in which welding can advantageously be substituted for riveting, with or without the possibilities which might be inherent in said corporation for salvaging costly equipment by the use of welding and thus saving annually large sums of money. E-4636.

ELECTRICAL ENGINEER, technical graduate; Mem. A. I. E. E., Assoc. Mem. of the Engineering Institute of Canada. Professional electrical engineer of British Columbia. Experience covers construction and maintenance of power and industrial and hydroelectric plants and substations. At present employed, but desires change. Location preferred, Western Canada. E-4637.

ELECTRICAL ENGINEER, technical graduate, G. E. Test, G. E. control engineering. 3 years' installation, operation general engineering and design anthracite coal fields. Age 29; desires position leading to commercial work, but will consider a position in other lines. E-4638.

TECHNICAL GRADUATE, young man 27 years of age, graduate of the Bliss Electrical Engineering School, one year telephone experience with the Western Electric Company, and five years' radio experience desires a position in the electrical or radio industry willing to start at a low salary if possibilities for advancement, not particular as to location, would prefer position in South America. E-4639.

MECHANICAL ENGINEER, age 22; two years' traveling experience doing inspection and testing work on electrical machinery for a large corporation; two years' experience teaching theoetical and applied electricity in a vocational school. Has also had some drafting experience. Desires a position as sales engineer or whatever you have to offer in the east. Available at once. E-4640.

ELECTRICAL ENGINEER, graduate engineer 1918 from University of Missouri; six months with Coast Artillery commissioned Second Lieutenant; two years' design, construction and operation of central station power plants, three years with large electrical manufacturing company designing and manufacturing switchboards for central stations. Desires broader field, preferably in central station design and construction. Salary $3600. Central states preferred. E-4641.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED DECEMBER 14, 1923

ABURTO, VICENTE, Switchboard Operator, Mexican Light & Power Co., El Oro, Mexico, Mex.

AGUILAR, JUAN, Division Superintendent, Mexican Light & Power Co., El Oro, Mexico, Mex.

*ALLEN, RICHARD WARREN, Engineer, Distribution Engg. Dept., Narragansett Electric Lighting Co., Turks Head Bldg., Providence; res., Wickford, R. I.

ANZINI, DANIEL IRWIN, Student, Testing Dept., General Electric Co., Schenectady, N. Y.

BATES, SHERRILL PETTIGREW, Estimate Engineer, Transformer Engg. Dept., General Electric Co., Pittsfield, Mass.

BEALL, IRL VERNON, Chief Electrician, U. S. S. "Morrill," U. S. Coast Guard, Detroit, Mich.

BELL, ST. JULIEN E., Electrical Engineer, General Electric Co., Schenectady, N. Y.

BERRY, EDWARD WARREN, Engineering Dept., Electric Specialty Co., 211 South St., Stamford, Conn.

BIDER, BERNARD, Electrical Draftsman, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

BOFINGER, P. ROBERT, Draftsman, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

BOICOURT, E. H., Local Manager, Iowa Light & Power Co., Rockwell City, Iowa.

BRUNNOCK, DENNIS JOSEPH, Inspector, Brooklyn Edison Co., Grand Ave., Brooklyn; res., New York, N. Y.

BUCKLEY, ANDREW FORREST, 111 W. 188th St., New York, N. Y.
BUELL, WALTER G., Operating Dept., Bureau of Power & Light, City of Los Angeles, 110 Front St., San Pedro, Calif.
BYL, DONALD HENNEGEN, Student, Testing Dept., General Electric Co., Schenectady, N. Y.
CABOT, GEORGE EDWARD, Partner, Cabot. Cabot & Forbes, 60 State St., Boston, Mass.
CANTRALL, OTTO L., Switchboard Specialist, General Electric Co., Atlanta, Ga.
*CARR, HAROLD FREMONT, Electrical Engineer, Switchboard Sales Dept., General Electric Co., Schenectady, N. Y.
CASPER, ROY MADISON, Design Engineer, Power Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
CHEVALLIER-RUFIGNY, JACQUES, Engineer, International General Electric Co., Schenectady, N. Y.
*CHURCHILL, COLIN FRANK, Asst. Residenr Engineer, William C. Olsen, Kingston; fot mail, Fayetteville, N. C.
CINTRA, JAYME, Locomotive Superintendent, Paulista Railway, Jundiahy, Sao Paulo, Brazil, S. A.
CLEVENSTINE, GEORGE G., Foreman, Outdoor Construction, Electric Power Equipment Corp., 412 N. 18th St., Philadelphia; res., Lebanon, Pa.
COLE, MILTON T., Electrical Draftsman, Dwight P. Robinson & Co., Inc., 125 E. 46th St., New York, N. Y.
DORMONT, JEAN, Engineer, Transformer Dept., General Electric Co., Pittsfield, Mass.
DYSON, WALTER, Electrical Instructor, Rehabilitation Dept., Georgia School of Technology, Atlanta, Ga.
ECCARDT, MICHAEL, Jr., Chief Electrician, Polar Wave Ice & Fuel Co., 3638 Olive St., St. Louis, Mo.
ELLIOTT, PARK, Electrical Engineer, General Electric Co., Pittsfield, Mass.
FARR, ALTON EVERETT, Manager & Owner, Waitsfield & Fayston Telephone Co., Waitsfield, Vt.
FARRAND, VAN DOREN, Wire Chief, Western Union Telegraph Co., Salt Lake City, Utah
FLETCHER, CHARLES NORMAN, Engineer, Messrs. Edward G. Herbert Ltd., Atlas Works., Chapel St., Levenshulme, Manchester; for mail, Cheshire, England.
FLINCHBAUGH, LOUIS DAVID, Substation Construction, Rochester Gas & Electric Corp. Rochester, N. Y.
FUCHS, WILLIAM, Electrician, Service Dept., A. B. See Elevator Co., 52 Vesey St., New York, N. Y.
GEORGE, HARRY FRANKLIN, Electrical Laboratory, Consumers Power Co., Jackson, Mich.
GRACEY, ARMINE LLOYD, Switchboard Engineer, Bell Telephone Co. of Penna., 261 N. Broad St., Philadelphia, res., Glenside, Pa.
HALE, RAYMOND O., Salesman, Westinghouse Elec. & Mfg. Co., 1224 Miners Bank Bldg., Wilkes-Barre, Pa.
HART, HARRY, Vice-President, S. & H. Electrical Works, 1422 W. Monroe St., Chicago, Ill.
HAYWARD, CHARLES S., Chief Electrician, Alabama Power Co., Muscle Shoals, Ala.
HAYWOOD, WENDELL ERNEST, Electrical Engineer, American Tel. & Tel. Co., 823 Boatmen's Bank Bldg., St. Louis, Mo.
HELLWIG, EMIL CARL, 1229 Champa St., Denver, Colo.
HERRICK, PAUL BERNARD, Student, School of Engg. of Milwaukee and Power Testing & Installation, Electric Meter Engineering Co., Milwaukee, Wis.
HILL, HAROLD OTTO, Transmission Engineer, Riter-Conley Co., 318 Oliver Bldg., Pittsburgh; res., Aspinwall, Pa.
HINZMAN, HENRY A., Electrical Superintendent, Harry A. Hanft, 142 W. 17th St., New York, N. Y.
HOBART, JOHN EVAN, Installation Dept., McClellan & Junkersfeld, Inc., Union Electric Co., St. Louis: for mail, East St. Louis, Ill.
HOPPE, ERNEST A., Laboratory Assistant, Genl. Engg. Lab., General Electric Co., Schenectady, N. Y.
HUBBARD, HORACE STIMPSON, Designing Engineer, Transformer Engg. Dept., General Electric Co., Pittsfield, Mass.
*HUXFORD, JAMES H., Jr., Switchboard Engineer, General Electric Co., Schenectady, N. Y.
JACKSON, FRANK W., Appraisal Engineer, Valuation & Engineering Dept., American Appraisal Co., Milwaukee, Wis.
JACOBS, LOUIS, c/o Hurwitz, 1130 Union Ave., New York, N. Y.
JEWSBURY, WILLIAM, Substation Leading Hand, Newcastle City Council, Newcastle; res., Waratah, N. S. W., Australia.
JONES, ELMER W., Teacher, Electrical Dept., Kansas State Teachers College, Pittsburgh, Kans.
KARANI, MINOCHER FRAMROZ, Chief Engineer, The Gwalior Cement Co., Ltd., Banmore, India.
KIRKWOOD, REYNOLDS FREDERICK, Electrical Engineer, Transformer Dept., General Electric Co., Pittsfield, Mass.
*KNODERER, CLAUDE LUTHER, Student Engineer, American Tel. & Tel. Co., 664 Bourse Bldg., Philadelphia, Pa.
KOETZLE, JOHN JACOB, Service Engineer, Westinghouse Elec. & Mfg. Co., 9th St. & 2nd Ave., Huntington, W. Va.
LEAVITT, HENRY JOSEPH, Teacher, Electrical Dept., Montpelier High School, 169 Main St., Montpelier, Vt.
LENNOX, THOMAS C., Electrical Engineer, General Electric Co., Pittsfield, Mass.
LITTLEWOOD, HERBERT S., Student, Westinghouse Elec. & Mfg. Co., East Pittsburgh; for mail, Wilkinsburg, Pa.
LONGBOTTOM, CLAUDE MULLER, W. & E. Hall Engineering Fellow, University of Queensland, Brisbane, Australia; for mail, New York, N. Y.
MACKAY, GEORGE MOIR JOHNSTONE, Research Engineer, Research Lab., General Electric Co., Schenectady, N. Y.
MARSHALL, LEONARD REID, Draughtsman, Southern Canada Power Co., Coristine Bldg., Montreal, Que., Can.
McDONELL, FRANK WILLIAMS, General Tester, New York Edison Co., 92 Vandam St., New York, N. Y.
McGLONE, JOHN, Patent Attorney, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
McKEE, PAUL B., First Vice-President & General Manager, The California Oregon Power Co., 216 W. Main St., Medford, Ore.
MOLINET, ENRIQUE, Asst. Electrical Engineer, Cuban American Sugar Co., Central Delicias, Oriente, Cuba.
MOXLEY, WILLIAM FRANCIS, Electrical Inspector, Glen Alden Coal Co., Scranton, Pa.
NAKASHIMA, TOMONASA, Professor of Electrical Engineering, Hamamatsu Technical College, Hamamatsu City, Japan; for mail, New York, N. Y.
NEMKOWSKI, BORUCH M., Electrical Inspector & Tester, Westinghouse Elec. & Mfg. Co., Newark; res., Paterson, N. J.
*OWSLEY, JOSEPH H., Draftsman, Puget Sound Power & Light Co., 401 Electric Bldg., Seattle, Wash.
PARRY, RONALD E. RICHMOND, Laboratory Assistant, General Electric Co., Schenectady, N. Y.
PAWSON, PERCY NORMAN, Asst. Mechanical & Electrical Engineer, Bradford Dyeing Association, Bradford; res., Westerley, R.I.
PAYNE, LINTORN SIMMONS, Asst. Electrical Engineer, Hydro-Electric Branch, Public Works Dept., Wellington, N. Z.
PETERSON, FRED W., Service Man, Westinghouse Elec. & Mfg. Co., 467-10th Ave., New York; res., Evergreen, L. I., N. Y.
*PFLIEGER, JOHN ALBERT, Statistical & Controllers Dept., Philadelphia Electric Co., 23rd & Market Sts., Philadelphia, Pa.
PIERCE, RAYMOND TRUSSELL, Electrical Engineer, Supply Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
PIERSON, WILLIAM MATHEWS, Asst. Superintendent, Electric Operating Dept., Adirondack Power & Light Corp., Schenectady, N. Y.
PLIEGO, MANUEL, Switchboard Operator, Mexican Light & Power Co., El Oro, Mexico, Mex.
PULSFORD, JAMES ARNOLD, Cadet Engineer, Public Service Electric Co., of N. J., River St., Newark; res., So. Orange, N. J.
PUTMAN, HENRY VAN DE VERE, Engineer, Ideal Electric & Mfg. Co., Mansfield, Ohio.
RANDOLPH, RUSSELL EDWARD, Electrical Foreman, Staten Island Shipbuilding Co., Mariners' Harbor; res., West New Brighton, S. I., N. Y.
REYSKEY, JOSEPH PAUL, Draftsman & Designer, Allis-Chalmers Mfg. Co., West Allis; res., Wauwatosa, Wis.
REZNICEK, JOSEPH, Foreign Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.
ROUSE, GEORGE H., Test Engineer, Fan Motor Special Test, General Electric Co., Pittsfield, Mass.
SCHOUW, ELVIN J., Draftsman, Allis-Chalmers Mfg. Co., West Allis; res., Milwaukee, Wis.
SCHULTZ, ANDREW S., Division Supt. of Installation, Western Electric Co., Inc., 1505 Race St., Philadelphia, Pa.
*SHAW, ALBERT EDWARD, Jr., Electrical Engineer, 334-73rd St., Brooklyn, N. Y.
SHEPHERD, HALL E., Student, John B. Stetson University, De Land, Fla.: for mail, Bronxville, N. Y.
SHIVE, EARLE HAGER, Asst. Load Dispatcher Philadelphia Electric Co., 1000 Chestnut St., Philadelphia; res., Collingdale, Pa.
SMART, HAROLD JOSEPH, Engineer, General Electric Co., Pittsfield; res., Dalton, Mass.
SNYDER, LEON GEORGE, Tester, Electrical Laboratory, Consumers Power Co., Jackson, Mich.
STEWART, SEYMOUR FLOYD, Student, Massachusetts Institute of Technology, 20 Charlesgate West, Boston, Mass.
STRAUS, FERDINAND N., Salesman & Correspondent, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.
TALLEY, W. EDWARD, Chief Engineer, Gunnell Bros. Co., Bristol, Va.
TALLMAN, JESSE JAMES, Chief Electrician, Union Lumber Co., Ft. Bragg, Calif.
WALKER, HARRY ROMAIN, Foreman, Electrical Repairs, Olds Motor Works, 920 W. Kalamazoo St., Lansing, Mich.
WALKER, H. B., Foreman, Horowhenua Electric Power Board, Levin, N. Z.
WALTER, CARL F., Electrical Construction Foreman, Northern Ohio Traction & Light Co., 59 N. High St., Akron; res., Kenmore, Ohio.
WEBSTER, JOSEPH S., Engineering Draftsman, Puget Sound Power & Light Co., 401 Electric Bldg., Seattle, Wash.
WHITNER, JOSEPH, Engineer, South-Eastern Underwriters Association, 533 Trust Co. of Georgia Bldg., Atlanta, Ga.
WICKEL, FRANCOIS APOLITE, Chief Electrician, M. S. "Missourian," American Hamdrian S. S. Co., 310 Sansome St., San Francisco, Calif.; for mail, Brooklyn, N. Y.

WIGGEN, EUGENE C., Tester, Light & Power Dept., Portland Railway, Light & Power Co., Electric Bldg., Portland, Ore.

WILSON, WILFRID ALBAN, Electrical Engineer, Commonwealth Steel Products Co., Ltd., Waratah, N. S. W., Australia.

WOODS, JOHN C., Electrical Draftsman, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

WORMULL, STANLEY JOHN, Telephone Engineer, Siemens Bros. & Co., Ltd., Woolwich Works; London, Eng.; for mail, Winnipeg, Can.

Total 104

*Formerly Enrolled Students.

ASSOCIATES RE-ELECTED DECEMBER 14, 1923

ADAMS, WILLIAM JAMES, Jr., Electrical Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.

ENDICOTT, THOMAS HART, Vice-President & General Manager, Green Equipment Corp., 260 Monadnock Block, Chicago, Ill.

ROSER, JOHN ORAM L., Sales Engineer, Transformer Accessory Sec., Central Station Dept., General Electric Co., Pittsfield, Mass.

MEMBERS ELECTED DECEMBER 14, 1923

ELLIS, BENSON OSBORN, Construction Engineer, 43 Cedar St., New York, N. Y.

LARABEE, ALFRED E., Major Signal Corps, U. S. Army War Dept., Washington, D. C.

McLAUGHLIN, ELWOOD FRANCIS, Dist. Manager, Railway & Lighting Dept., General Electric Co., Atlanta, Ga.

MUFFLEY, RAY U., Manager, Washington Coast Utilities, 620 New York Block, Seattle, Wash.

OST, PAUL JAMES, Asst. City Engineer in Charge of Electrical Work, City Hall, San Francisco, Calif.

SLAUGHTER, NUGENT HUNTER, Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.

TRANSFERRED TO GRADE OF FELLOW DECEMBER 14, 1923

PETERS, JOHN FINDLEY, Technical Assistant, Transformer Engineering Dept., Westinghouse Electric & Mfg. Co , East Pittsburgh, Pa.

TRANSFERRED TO GRADE OF MEMBER DECEMBER 14, 1923

ALEXANDER, PETER P., Research Engineer, Thomson Research Laboratory, General Electric Co., West Lynn, Mass.

BECKETT, B. B., Consulting Electrical Engineer San Francisco, Calif.

CANAVACIOL, FRANK E., Instructor, Department of Electrical Engineering, Polytechnic Institute, Brooklyn, N. Y.

CURTIS, MARSTON, General Electric Co., Duluth, Minn.

GARMAN, HARRY O., Consulting Engineer, Indianapolis,.Ind.

HALE, GEORGE R., Electrical Engineer, Canada Carbide Co., Shawinigan Falls, Quebec, Can.

HARWOOD, PAISLEY B., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

LEWIS, JOSEPH FRAZIER, Assistant to Manager, Pringle Electrical Mfg. Co., Philadelphia, Pa.

MEYER, HERBERT W., Statistical Engineer, Northern States Power Co., Minneapolis, Minn.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held December 10, 1923, recommended the following members for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

CLARK, WALTER G., Consulting Engineer, New York, N. Y.

JEFFERIES, ERNEST SMITH, Electrical Engineer, Steel Company of Canada, Ltd., Hamilton, Ont.

JEFFREY, FRASER, Electrical Engineer, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

STRATTON, SAMUEL W., President, Massachusetts Institute of Technology, Cambridge, Mass.

To Grade of Member

FLASHMAN, H. W., Sales Engineer, Westinghouse Electric International Co., Sydney, Australia

FREDERICK, HALSEY A., Electrical Engineer, Research Department, Western Electric Co., New York, N. Y.

KENNEDY, COLIN B., President, Colin B. Kennedy Corp., St. Louis, Mo.

MOMMO, ERNST J., Laboratory Assistant, Public Service Electric Co., Irvington, N. J.

PURINTON, RALPH B., Electrical Engineer, General Electric Co., Chicago, Ill.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before January 31, 1924.

Abbey, S. H., General Electric Co., Schenectady, N. Y.

Abbott, L. E., Union Gas & Electric Co., Cincinnati, Ohio

Adelsten, K. O., American Tel. & Tel. Co., New New York, N. Y.

Albert, R. M., 1898 Daly Ave., New York, N. Y.

Almquist, C. O., Queens Electrical Equipment' Flushing, N. Y.

Anderson, B. E., Great Western Power Co., Berkeley, Calif.

Anderson, C. A., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Anderson, R. G., Commonwealth Edison Co., Chicago, Ill.

Anderson, T. C., Westinghouse Elec. & Mfg. Co., Chicago, Ill.

Annis, J. B., Kansas City Power & Light Co., Kansas City, Mo.

Appleman, F. C., University of Minnesota, Minneapolis, Minn.

Aronson, S., New York Edison Co., New York, N. Y.

Axman, B., General Electric Co., Schenectady, N. Y.

Baldwin, E. N., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Balson, D. W., The Packard Electric Co., Warren, Ohio

Barclay, A. J., New York Edison Co., New York, N. Y.

Barenscher, P. J., University of Wisconsin, Madison, Wis.

Barker, O., Brooklyn Edison Co., Brooklyn, N. Y.

Barnes, W. A., Electrical Testing Laboratories, New York, N. Y.

Barnet, J. H., Portland Ry., Lt. & Pr. Co., Portland, Ore.

Barr, J. R., New York Edison Co., New York, N. Y.

Bauer, R. G., H Koppers Co., Pittsburgh, Pa.

Beadle, W. J., Philadelphia Rapid Transit Co., Philadelphia, Pa.

Beauman, L. R., Illinois Power & Light Corp., Decatur, Ill.

Becker, J. P., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Behrens, W. J., Commonwealth Edison Co., Chicago, Ill.

Bell, A., Toronto Hydro-Elec. System, Toronto, Ont.

Berg, S. A., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Bernhardt, C. P., Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.

Berry, H. R., Pacific Tel. & Tel. Co., San Francisco, Calif.

Berry, T. L., Jr., C. &. P. Tel. Co. of Baltimore, Baltimore, Md.

Beyers, A. P., Consumers Power Co., Jackson, Mich.

Blankenbuehler, J. H., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Blessing, E. C., Western Electric Co., Inc., New York, N. Y.

Boardman, R. L., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Body, H. T., Siemens Bros. & Co., Ltd., Winnipeg, Manitoba, Can.

Bohl, C., Consumers Power Co., Jackson, Mich.

Boice, M. C., Public Service Co., Waukegan, Ill.

Bond, E. D., Automobile Electrician, Baltimore, Md.

Bonifield, H. M., New York Telephone Co., New York, N. Y.

Bossard, G. L., Bossard Railway Signal Co., Troy, N. Y.

Boxer, J., Washington Electric Co., New York, N. Y.

Braam, A. E., School of Engg. of Milwaukee, Milwaukee, Wis.

Braden, R. A., University of Minnesota, Minneapolis, Minn.

Braun, E. H., Duquesne Light Co., Pittsburgh, Pa.

Bricks, H. M., General Electric Co., Bloomfield, N. J.

Bristol, W. A., Bell Telephone Co. of Pa., Philadelphia, Pa.

Brockmeyer, E. W., The Master Electric Co., Dayton, Ohio

Brown, C. C., Bell Tel. Co. of Pa., Philadelphia, Pa.

Brown, C. E., Public Service Production Co., Newark, N. J.

Brown, C. W., Kansas City Power & Light Co., Kansas City, Mo.

Brown, R. D., Monogahela West Penn Public Service Co., Fairmount, W. Va.

Bruning, W. H., American Tel. & Tel. Co., Chicago, Ill.

Bublitz, Z. P., School of Engineering of Milwaukee, Milwaukee, Wis.

Buchanan, A. B., Detroit Edison Co., Detroit, Mich.

Bucher, G. H., (Member), Westinghouse Elec. Internat'l Co., New York, N. Y.

Budenbom, H. T., Western Electric Co., New York, N. Y.

Buehl, L. H., Jr., Bell Telephone Co. of Pa., Philadelphia, Pa.

Bunting, R., General Electric Co., Schenectady, N. Y.

Burnell, W. R., American Tel. & Tel. Co., Chicago, Ill.

Burns, M. R., New York Edison Co., New York, N. Y.

Busch, A. J., Western Electric Co., Inc., New York, N. Y.

Busher, J. E., Kansas City Power & Light Co., Kansas City, Mo.

Butler, R. L., Central Hudson Gas & Electric Co., Poughkeepsie, N. Y.

Cadwell, N. R., Cleveland Elec. Ill. Co., Cleveland, Ohio

Callahan, W. J., New York Edison Co., New York, N. Y.

Carlovitz, G. H., (Member), Vanderbilt University Nashville, Tenn.

Carlson, A., (Member), Singer Mfg. Co., Truman, Ark.

Carmichael, J., Western Electric Co., Inc., Brooklyn, N .Y.

Carpenter, J. A., New York Edison Co., New York, N. Y.

Case, C. E., Cornell University, Ithaca, N. Y.

Casper, W. L. (Member), Western Electric Co., Inc., New York, N. Y.

Catchpole, L. A., Britannia Mining & Smelting Co., Britannia Beach, B. C., Can.

Chapman, G. C., General Electric Co., New York, N. Y.
Chapman, R. L., C. M. & St. P. Railway, Deer Lodge, Mont.
Chie, J., College of Elec. Engg., Marquette Univ., Milwaukee, Wis.
Chunn, W., Wisconsin Tel. Co., Milwaukee, Wis.
Church, L. H., Kansas State Agricultural College, Manhattan, Kansas.
Clark, W. A., New York Edison Co., New York, N. Y.
Clarke, T. H., Pacific Gas & Electric Co., San Francisco, Calif.
Clipson, L. T., Timken Roller Bearing Co., Columbus, Ohio.
Cloud, H. R., Central Indiana Power Co., Indianapolis, Ind.
Codemo, F. V., New York Edison Co., New York, N. Y.
Coles, C. F., Westinghouse Elec. & Mfg Co., E. Pittsburgh, Pa.
Conrad, P. M., General Electric Co., Schenectady, N. Y.
Cooper, R. J., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Copeland, W. G., (Member), Illinois Pr. & Lt. Co., Chicago, Ill.
Costa, M. P., New York Edison Co., New York, N. Y.
Cox, F., Cleveland Electric Ill. Co., Cleveland, Ohio
Crockett, R. V., Bluestone Power Station, Pocahontas, Va.
Crosby, W. W., New York Edison Co., New York, N. Y.
Cummings, G. F., New York Edison Co., New York, N. Y.
Cummings, J. S., New York Telephone Co., New York, N. Y.
Cundall, L. A., Bethlehem Steel Co., Lackawanna, N. Y.
Cunningham, J. M., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Curran, T. H., D. L. & W., Railroad, Hoboken, N. J.
Currie, F. L., School of Engg. of Milwaukee, Milwaukee, Wis.
Cushman, E. F., Price Bros. & Co., Ltd., Kenogami, P. Q.
Cushman, R. W., New England Power Co., Readsboro, Vt.
Dahl, H. A., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Dalrymple, E. R., Westinghouse Elec. & Mfg. Co., E. Pittsburgh. Pa.
Das, J. P., General Electric Co., Schenectady, N. Y.
Davidson, C. C , General Electric Co., Ft. Wayne, Ind.
de Bonneval, H. A., New York Edison Co., New York, N. Y.
DeCamp, R., Montana Power Co., Wolf Creek, Mont.
De Langen, T., Consumers Power Co., Jackson, Mich.
De Turk, E. F., Metropolitan Edison Co., Reading, Pa.
Dispennette, C. D., (Member), Andrews Steel Co., Newport, Ky.
Dodd, M., (Member), Commercial Cable Co., New York, N. Y.
Dodge, J. W., General Electric Co., Schenectady, N. Y.
Doolittle, W. P., Kansas City Power & Light Co., Kansas City, Mo.
Doremus, F. H., General Electric Co., Schenectady, N. Y.
Doss, G. J., General Electric Co., Ft. Wayne, Ind.
Douden, P. A., Globe Electric Supply Co., Denver, Colo.
Downie, J. M., General Electric Co., Schenectady, N. Y.
Drake, W. A., Western Electric Co., New York, N. Y.
Drewett, G. A., General Electric Co., Schenectady, N. Y.
Drost, H. F., Commonwealth Edison Co., Chicago, Ill.
Dunning, S. C., (Member), Carmel Light & Power Co., Inc., Carmel, N. Y.
Ebert, E. Jr., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Edmonds, W. O., Kansas City Power & Light Co., Kansas City, Mo.
Egee, A. H., Philadelphia Electric Co., Philadelphia, Pa.
Eldridge, C. C., Jr., Bell Telephone Co., of Pa., Philadelphia, Pa.
Ellenberg, Fred, 62 Wall St., Staten Island, N. Y.
Ellsworth, P. R., Cleveland Electric Ill. Co., Cleveland, Ohio.
Elminger, H.H., New York Edison Co., New York, N. Y.
Elz, G. A., 86 Orchard St., Jamaica Plain, Mass.
Evans, J. R., Commonwealth Edison Co., Chicago, Ill.
Falquet, J. E., Union Gas & Electric Co., Cincinnati, Ohio
Farnsworth, H. D., So. California Edison Co., Los Angeles, Calif.
Farntham, D., Canadian General Electric Co., Toronto, Ont.
Fearn, R. L., Jr., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Fielder, G. H., Rochester Gas & Elec. Corp., Rochester, N. Y.
Fischer, H. W., N. W. Bell Telephone Co., Minneapolis, Minn.
Fisler, C. E., Adirondack Power & Light Co., Schenectady, N. Y.
Fleming, T. J., The Pacific Tel. & Tel. Co., Los Angeles, Calif.
Flynn, F. A., Cleveland Electric Ill. Co., Cleveland, Ohio
Forbes, B. G., Stone & Webster, Inc., Boston, Mass.
Foster, W. C., Portland, Ry. Lt. & Pr. Co., Portland, Ore.
Fountain, H. A., The Ohio Public Service Co., Cleveland, Ohio
Fowler, C. V., (Member), The Pacific Tel. & Tel. Co., San Francisco, Calif.
Fowler, H. E., New York Edison Co., New York, N. Y.
Frazier, J. L., (Member), Hendrie & Bolthoff M. & S. Co., Denver, Colo.
Frederick, P., General Electric Co., Schenectady, N. Y.
Fredrikson, H. W., New York Edison Co., New York, N. Y.
Frei, C., Jr., General Electric Co., New York, N.Y.
Frend, J. J., National Dist. Telegraph Co., New York, N. Y.
Fugill, A. T., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Fulner, R. L., Cin. & Sub. Bell Telephone Co., Cincinnati, Ohio
Gadbois, J. S., Lyme Electric Power Co., Niantic, Conn.
Garman, F. R., Bell Telephone Co. of Pa., Philadelphia, Pa.
Garner, W. G., Rocky Mountain Radio Corp., Ogden, Utah.
Garterman, J., Stone & Webster Inc., Boston, Mass.
Geiselman, R. A., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
George, R. H., Purdue University, Lafayette, Ind.
Ghirardi, A. A., J. Livingston & Co., New York, N. Y.
Gibbons, J. J., Wisconsin Telephone Co., Milwaukee, Wis.
Gildersleeve, T. S., Philadelphia Electric Co., Philadelphia, Pa.
Gillham, J. M., (Member), Kansas City Pr. & Lt. Co., Kansas City, Mo.
Ginna, R. E., Brooklyn Edison Co., Brooklyn, N. Y.
Giordmaina, J. N., Swift Canadian Co., Ltd., W. Toronto, Ont., Can.
Glasier, R. C., Western Electric Co., Inc., New York, N. Y.
Goodale, H. I., Federal Tel. & Tel. Co., Buffalo, N. Y.
Graef, J. R., New York Edison Co., New York, N. Y.
Greco, A. J., Brooklyn Polytechnic Institute, Brooklyn, N. Y.
Green, F., with C. H. Tenney Co., Cambridge, Mass.
Greensward, J. D., Allis-Chalmers Mfg. Co., Wauwatosa, Wis.
Gregory, L. J., Union Gas & Electric Co., Cincinnati, Ohio
Grettum, L. A., Wisconsin Ry. Lt. & Pr. Co., Winona, Minn.
Griffing, R. A., (Member), Harlem Valley Elec. Corp., Pawling, N. Y.
Griscom, S. B., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Groat, E. T., General Electric Co., Schenectady, N. Y.
Grotsinger, J., Goodyear Tire & Rubber Co., Akron, Ohio
Grzybowski, J. M., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Guilbert, N. R., Elevator Safety Appliance Co., Philadelphia, Pa.
Gunsolley, V. V., Kansas City Power & Light Co., Kansas City, Mo.
Hague, K. H. S., Ferranti Meter & Trans. Mfg. Co., Toronto, Ont.
Haines, C. J., School of Engg. of Milwaukee, Milwaukee, Wis.
Haines, G. E., Western Electric Co., Inc., Chicago, Ill.
Haines, H. R., So. California Edison Co., Big Creek, Calif.
Halstead, J. M., Kansas City Power & Light Co., Kansas City, Mo.
Hamilton, S., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Hanna, C. R., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Hare, R. J., So. California Tel. Co., Los Angeles, Calif.
Harkin, P., New York Edison Co., New York, N. Y.
Harness, G. C., Penn. Power & Light Co., Hazleton, Pa.
Hatheway, D. H., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Hasenritter, D., Union Electric Light & Power Co., Webster Groves, Mo.
Hauser, A., Mexican Light & Power Co., Mexico D. F., Mex.
Havens, H. B., Student, 12401 Osceola Ave., Cleveland, Ohio.
Hayden, J. F., Duquesne Light Co., Pittsburgh, Pa.
Haynes, H., Kansas City Power & Light Co., Kansas City, Mo.
Hayward, H. W., United Elec. Railways Co., Providence R. I.
Heberlein, A. A., American Tel. & Tel. Co., New York, N. Y.
Hedger, H. C., E. L. Phillips & Co., L. I. Ltg. Co., New York, N. Y.
Hedren, I., New York Edison Co., New York, N. Y.
Heffner, R. J., Pacific Tel. & Tel. Co., San Francisco, Calif.
Heidelberger, O., Univ. of Minnesota, Minneapolis, Minn.
Heisler, S. E., Pennsylvania Power & Light Co., Hazelton, Pa.
Hendrixson, L. H., Bell Tel. Co., of Pa., Philadelphia, Pa.
Herrman, W. J., Louisiana State University, Baton Rouge, La.
Hieronymus, T. G., Kansas City Power & Light Co., Kansas City, Mo.
Hill, W. R., United Elec. Light & Power Co., New York, N. Y.
Hinkle, F., The Ohio Bell Telephone Co., Akron, Ohio.
Hockley, W., British Columbia Elec. Ry. Co., Vancouver, B. C.

Hockman, H. G., Beattie Electric Light Co., Beattie, Kans.
Holbeck, J. I., University of Minnesota, Minneapolis, Minn.
Holmberg, A., New York Edison Co., New York, N. Y.
Honsaker, H. H., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Hooven, M. D., Jr., Public Service Electric Co., Newark, N. J.
Huppert, W., New York Edison Co., New York, N. Y.
Hutchinson, H. C., General Electric Co., Schenectady, N. Y.
Jackson, L. W., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Jackson, H. R., Union Gas & Electric Co., Cincinnati, Ohio
Jallevato, W. J., University of So. California, Los Angeles, Calif.
Jefferis, A. C., Fitch-Jefferis Co., Cheyenne, Wyoming.
Jewell, N. H., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Johnston, A. T., Union Switch & Signal Co., Swissvale, Pa.
Jones, A. P., Interboroguh Rapid Transit Co., New York, N. Y.
Jones, O. M., Duquesne Light Co., Pittsburgh, Pa.
Juers, J. H., Cutler-Hammer Mfg. Co., New York, N. Y.
Jungmann, S., New York Edison Co., New York, N. Y.
Kammer, H. A., New York Edison Co., New York, N. Y.
Kamphausen, R. C., Western Electric Co., Inc., New York, N. Y.
Kaplan, A., with S. Kaplan, New York, N. Y.
Kapysheff, G. J., New York Edison Co., New York, N. Y.
Karkalos, A. A., West Penn Power Co., Pittsburgh, Pa.
Keller, H. W., Timken Roller Bearing Co., Columbus, Ohio.
Kendall, P. M., Westinghouse Elec. & Mfg. Co., Boston, Mass.
Kenealy, E. J., Div. of Light & Power, City Hall, Cleveland, Ohio
Kettler, A., Public Service Production Co., Newark, N. J.
Kidd, W. J., 212 E. College Ave., State College, Pa.,
Kimbell, J. F., Baker Iron Works, Los Angeles, Calif.
Kimberly, M. C., Commonwealth Edison Co., Chicago, Ill.
King, S. H., Bell Tel. Co. of Pa., Pittsburgh, Pa.
King, W. E., United Electric Light & Power Co., New York, N. Y.
Kirkland, E. H., Jr., Mountain States Power Co., Albany, Ore.
Kleinberger, R. C., Grandin Singer Corp., New York, N. Y.
Klenze, R. O., Board of Education, Chicago, Ill.
Knapp, M. M., U. S. Bureau of Census, Washington, D. C.
Knerr, B. C., Merkle Machinery & Contracting Co., Kansas City, Mo.
Knettles, H. R., Western Electric Co., Inc., New York, N. Y.
Knudson, N. K., New York Edison Co., New York, N. Y.
Kohl, W. C., Century Electric Co., Boston, Mass.
Kreek, L. F., Mass. Institute of Technology, Cambridge, Mass.
Kubler, E. F., 4468 Blvd., Union Hill, N. J.
Kuhlmeyer, N. F., Western Union Tel. Co., San Francisco, Cal.
Kuhn, C. E., British Columbia Electric Railway Co., Ltd., Vancouver, B. C.
Kutman, J., New York Edison Co., New York, N. Y.
La Favour, L., Michigan State Telephone Co., Detroit, Mich.
Laffoon, C. M., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa..
Laib, R. D., The Packard Electric Co., Warren, Ohio
Lake, A. R., Commonwealth Edison Co., Chicago, Ill.
Lalor, J. Q., O. H. Davidson Equipment Co., Denver, Colo.
Lancaster, R. D., Western Electric Co., Inc., Chicago, Ill.
Lannon, J. V., Metropolitan Edison Co., Reading, Pa.
Larson, C. A., Public Service Co., of Colorado, Lacombe Station, Denver, Colo.
Lauder, A. H., General Electric Co., Schenectady, N. Y.
Leffler, W. S., (Member), Brooklyn Edison Co., Brooklyn, N. Y.
Lehmann, A., Jr., New York Edison Co., New York, N. Y.
Lehnen, E. J., School of Engineering of Milwaukee, Milwaukee, Wis.
Lenehan, B. E., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Lewis, F., Jr., Bell Telephone Co., Carnegie, Pa.
Lindell, A. G., Goodman Mfg. Co., Chicago, Ill.
Linhoff, C. H., General Electric Co., Schenectady, N. Y.
Linusson, R., New York Edison Co., New York, N. Y.
Llorens, F. L., The Manati Sugar Co., Manati, Oriente, Cuba.
Long, J. A., New York Telephone Co., New York, N. Y.
Lyman, A. F., New York Telephone Co., New York, N. Y.
Lynn, J. H., Kansas City Power & Light Co., Kansas City, Mo.
MacDonald, J. Q., Globe Grain & Milling Co., Ogden, Utah
MacDonald, M. M., Andrews Steel Co., Newport, Ky.
Maher, W. J., United Elec. Light & Power Co., New York, N. Y.
Mahle, H. J., Cons. Gas, Elec. Lt. & Pr. Co., Baltimore, Md.
Mahnke, E. C., 206 E. Maumee St., Angola, Ind.
Maine, B. C., General Electric Co., Schenectady, N. Y.
Martin, G. J., Drexel Institute, Philadelphia, Pa.
Masin, O. F., Ford Instrument Co., Long Island, City, N. Y.
Mason, W. P., Western Electric Co., Inc., New York, N. Y.
Matheny, J. D., School of Engg. of Milwaukee, Milwaukee, Wis.
Matheo, A. B., with T. E. Murray, Inc., New York, N. Y.
Mattson, N. E., Western Electric Co., Seattle, Wash.
Maxson, R. D., Public Service Co., of No. Illinois, Chicago, Ill.
Mayfield, W. W., No. Missouri Power Co., Excelsior Springs, Mo.
McCall, D. H., Western Union Telegraph Co., San Francisco, Calif.
McCarthy, C. J., Columbia University, New York, N. Y.
McClenahen, R. A., Public Service Production Co., Camden, N. J.
McClelland, J. P., Bell Telephone Co. of Canada, Montreal, Que.
McCormick, H. L., Consolidated Gas, Elec. Lt. & Pr. Co., Baltimore, Md.
McLenegan, D. W., General Electric Co., Schenectady, N. Y.
McMahan, R., Marquette University, Milwaukee, Wis.
McMullen, G. P., Rideau Power Co., Merrickville, Ontario, Can.
McNaughton, E. F., San Francisco-Oakland Terminal Rys., Oakland, Calif.
Meijling, P. J., Adirondack Power & Light Corp., Schenectady, N. Y.
Mergenthaler, A., New York Edison Co., New York, N. Y.
Millea, L., 206 West St., Worcester, Mass.,
Mitchell, E. R., Union Gas & Electric Co., Cincinnati, Ohio
Moller, T. B., Gibbs & Hill, New York, N. Y.
Mooney, J. P., United Electric Light & Power Co., New York, N. Y.
Moore, J. I., Philadelphia Electric Co., Philadelphia, Pa.
Morin, C. B., The Ohio Power Co., Tiffin, Ohio
Morris, L. P., Westinghouse Elec. & Mfg. Co., Cincinnati, Ohio
Morrison, S. D., Western Electric Co., Inc., New York, N. Y.
Morton, A. H., Radio Corp. of America, New York, N. Y.
Mossige, A. S., New York Edison Co., New York, N. Y.
Moulds, M. H., New York Edison Co., New York, N. Y.
Mudgett, G. F., Westinghouse Elec. & Mfg. Co., South Bend, Ind.
Myers, R. B., Iowa State College, Ames, Iowa
Myers, R. W., The Packard Electric Co., Warren, Ohio
Nangle, W. O., Western Electric Co., Inc., Chicago, Ill.
Nassen, H. S K., New York Edison Co., New York, N. Y.
Nollenberger, T. C., Jr., Elec. Contr. & Constr., Denver, Colo.
Ogden, H. S., General Electric Co., Schenectady, N. Y.
Oleson, F. L., Illinois Pacific Glass Co., San Francisco, Cal.
Oplinger, K. A., Purdue University, Lafayette, Ind.
Ortiz, J. P., New York Edison Co., New York, N. Y.
Osborne, D. C., New York Telephone Co., New York, N. Y.
Oscarson, G. L., Electric Machinery Mfg. Co., Chicago, Ill.
Osterman, A. H., Bell Telephone Co. of Pa., Philadelphia, Pa.
Paiste, H. C., Northern Ohio Traction & Light Co., Akron, Ohio
Palm, S. M., The Bell Telephone Co., of Pa., Philadelphia, Pa.
Palmer, G. W., Brooklyn Edison Co., Brooklyn, N. Y
Palmer, J. S., Kansas City Power & Light Co,. Kansas City, Mo.
Parker, L. W., (Member), Western Electric Co., Inc., New York, N. Y.
Parnell, W. C., Stevens & Wood, Inc., New York, N. Y.
Parr, J. C. A., New York Edison Co., New York, N. Y.
Pearcy, N. C., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Pedro, G. F., Brooklyn Polytechnic Inst., Brooklyn, N. Y.
Pendleton, L. L., Philadelphia Co., Pittsburgh, Pa.
Perlstein, P., See Gate, Brooklyn, N. Y.
Permanson, O. E., New York Edison Co., New York, N. Y.
Pernick, A., 401 Georgia Ave., Brooklyn, N. Y.
Pesonen, E. F., New York Edison Co., New York, N. Y.
Peterson, J. B., United Electric Light & Power Co., New York, N. Y.
Piper, C. E., Jr., Day & Zimmerman Construction Co., Tyrone, Pa.
Piper, W. J., Detroit Edison Co., Detroit, Mich.
Pittinger, F. H., Kansas City Power & Light Co., Kansas City, Mo.
Plotkin, J., New York Edison Co., New York, N. Y.
Plumley, G. C., Western Electric Co., Inc., Chicago, Ill.
Polkinghorn, F. A., U. S. Navy Dept., Mare Island, Calif.
Porter, R. T., Alabama Power Co., Montgomery, Ala.
Price, J. R., Western Electric Co., New York, N. Y.
Pringle, A. E., Bell Telephone Co. of Pa., Harrisburg, Pa.
Pyror, E. G. S., Underwriters Laboratories, Seattle, Wash.

Purdom, O. V., Western Electric Co., Chicago, Ill.
Quirmbach, C. F., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Rall, A. A., Kansas City Power & Light Co., Kansas City, Mo.
Reid, T. A., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Reinmann, F. L., No. Indiana Gas & Elec. Co., Hammond, Ind.
Rich, R. A., Jr., General Electric Co., New York, N. Y.
Richards, C. R., (Member), Lehigh University, Bethlehem, Pa.
Richardson, A. G., Brooklyn Polytechnic Institute, Brooklyn, N. Y.
Richardson, A. W., Westinghouse Elec. & Mfg. Co., Toledo, Ohio.
Richardson, L. W., General Electric Co., Schenectady, N. Y.
Rieke, C. R., Commonwealth Edison Co., Chicago, Ill.
Rivas, H., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Roach, C. L., New Brunswick Telephone Co., St. John, N. B.
Robertson, E. B., (Member), Rwy. & Industrial Engg. Co., Greensburg, Pa.
Robles, G., Alberto Isaack & Co., Mexico D. F., Mex.
Rockwood, A. C., General Electric Co., Schenectady, N. Y.
Rodriguez, J. M., Jr., Electrical Contractor, Brooklyn, N. Y.
Rogers, R. W., Public Service Co., of No. Illinois, Chicago, Ill.
Rolland, J., New York Edison Co., New York, N. Y.
Rose, E. L., California Institute of Technology, Pasadena, Calif.
Rosenberger, H. J., All America Cables, Inc., New York, N. Y.
Roth, F. W., Duquesne Light Co., Pittsburgh, Pa.
Round, G. V., General Electric Co., Lynn, Mass.
Routson, L. B., Western Union Tel. Co., New York, N. Y.
Ruge, H. P., Commonwealth Edison Co., Chicago, Ill.
Russell, M. F., Kansas City Power & Light Co., Kansas City, Mo.
Russell, N. D., Century Electric Co., Philadelphia, Pa.
Rutherford, P. H., General Electric Co., Lynn, Mass.
Rykert, W. C., Armour Inst. of Technolgy, Chicago, Ill.
Sacis, C. F. (Menber) Western Electric Co., New York, N. Y.
Sanders, C. W., Va-Western Power Co., Charlottesville, Va.
Sauer, L. E., Westinghouse Elec. & Mfg. Co., E. Pitts:urgh, Pa.
Savage, W. S., Toronto Transportation Comm., Toronto, Ont.
Sawyer, R. T., General Electric Co., Erie, Pa.
Scadding, S. C., Bell Telephone Co. of Canada, Montreal, Que.
Schallis, O. A., New York Edison Co., New York, N. Y.
Schatzle, F. J., J. A. P. Crisfield Construction Co., Devon, Conn.
Schatz, N., General Electric Co., Lynn, Mass.
Schlenker, V. A., Western Electric Co., Inc., New York, N. Y.
Schlottere, E. L., The Counties Gas & Elec. Co., Norristown, Pa.
Schmidt, M., American Radio & Research Corp., New York, N. Y.
Schneider, E., Brown Instrument Co., Wayne Junction, Philadelphia, Pa.
Schroeder, H., (Member), Edison Lamp Works, Harrison, N. J.
Schuele, A. G., Elec. Testing Laboratories, New York, N. Y.
Schultz, J., 511 W. Gale St., Angola, Ind.
Schulze, R. C. R., Duquesne Light Co., Pittsburgh, Pa.
Schurenberg, E. J., General Electric Co., Ft. Wayne, Ind.
Schwager, A. C., Elec. Testing Laboratories, New York, N. Y.
Scott, L. W., Hamburg Gas & Electric Co., Hamburg, Pa.
Seaburg, H., New York Edison Co., New York, N. Y.
Sevin, D. B., Eastern Connecticut Power Co., Uncasville, Conn.
Sheirs L. M., Mexican Light & Power Co., Mexico City, Mex.
Sheridan, C. J., Electric Specialty Co., Stamford, Conn.
Shill, P. W., Toronto Hydro-Electric System, Toronto, Ont.
Silk, J. L., New York Edison Co., New York, N. Y.
Sills, H. R., Canadian General Electric Co., Ltd., Peterborough, Ont.
Silvey, W. R., New York Telephone Co., New York, N. Y.
Simmons, I. H., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Simpson, W. G., New York Edison Co., New York, N. Y.
Sinanian, H., New York Edison Co, New York, N. Y.
Skogland, A. G., Stone & Webster, Inc., Boston, Mass.
Slobin, H., United Electric Light & Power Co., New York, N. Y.
Smith, E. V., Western Electric Co., Inc., Detroit, Mich.
Smith, F. W., Mexican Light & Power Co., Necaa, Pue., Mexico.
Smith, McN., General Electric Co., Schenectady, N. Y.
Snyder, L. V., Westchester Lighting Co., Mt Vernon, N. Y.
Sorensen, J. E., Western Electric Co., Inc., Chicago, Ill.
Spaulding, G. W., Union Electric Light & Power Co., St. Louis, Mo.
Spease, J. F., General Electric Co., Schenectady, N. Y.
Speer, F. R., Scranton Electric Co., Scranton, Pa.
Sprague, D. L., California Edison Co., Big Creek, Calif.
Sprinkle, G. B., Union Gas & Electric Co., Cincinnati, Ohio
Stahlnecker, E. H., New York Edison Co., New York, N. Y.
Stanfield, A., Union Gas & Electric Co., Cincinnati, Ohio
Steding, L., Union Gas & Electric Co., Cincinnati, Ohio
Steele, R. B., Western Electric Co., New York, N. Y.
Stiles, A. L., Bell Tel. Co., of Pa., Philadelphia, Pa.
Strack, E. V., New York Tel. Co., New York, N.Y.
Strong, R. W., 501 W. Mt. Pleasant Ave., Mt. Airy, Philadelphia, Pa.
Sussan, P., New York Edison Co., New York, N. Y.
Sweet, R. G., Eastern Connecticut Power Co. Willimantic, Conn.
Synwoldt, W. F., New York Edison Co., New York, N. Y.
Taintor, C. W., (Member), Gila Valley Power District, Yuma, Arizona.
Tanner, W., New York Edison Co., New York, N. Y.
Thompson, D. O., Public Service Co. of No. Ill., Evanston, Ill.
Thompson, E. A., Southwestern Bell Tel. Co., Topeka, Kans.
Thompson, P. C., New York Tel. Co., New York, N. Y.
Thompson, T. C., Crosby Steam Gage & Valve Co., Charlestown, Mass.
Tobias, A. M., (Member), Westinghouse Lamp Co., Bloomfield, N. J.
Tompkins, R. J., Citizens Gas & Electric Co., Waterloo, Iowa
Traiser, L. M., Chicago Surface Lines, Chicago, Ill.
Travis, B. A., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Troedsson, H., Stone & Webster, Inc., Boston, Mass.
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Ullman, S. H., New York Edison Co., New York, N. Y.
Uhrmann, F. J., Wextern Electric Co., Inc., Philadelphia, Pa.
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Van Giesen, I. D., Victor G. Mendoza Co., Havana, Cuba
Van Rye, O., Cia. Elec. de Alumbrado & Trac., Santiago, Cuba
Van Wyck, J. R., Viele, Blackwell & Buck. New York, N. Y.
Viall, E. F., Finlay Engineering College, Kansas City, Mo.
Vincent, F. W. S., Granby Mining, Smelting & Power Co., Anyox, B. C., Can.
Voepel, O. A., Kansas City Power & Light Co., Kansas City, Mo.
von Sothen, C. E. H., General Electric Co., Schenectady, N. Y.
Wade, A. J., General Electric Co., Portland, Ore.
Wagner ,M. J., New York Edison Co., New York, N. Y.
Walker, W. G., Philadelphia Electric Co., Philadelphia, Pa.
Walmsley, G., Manomet Mill 3, New Bedford, Mass.
Walters, C. R., Automotive Electrician, Harrisburg, Pa.
Wang, C. C., General Electric Co., Schenectady, N. Y.
Warner, A. S., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Watkins, M. C., Commonwealth Edison Co., Chicago, Ill.
Watson, H. H., General Electric Co., Schenectady, N. Y.
Weil, J., University of Florida, Gainesville, Fla.
Weldon, H. S., Canadian Inspection & Testing Co., Ltd., Toronto, Ont.
Welk, R., New York Edison Co., New York, N. Y.
Wells, J. T., New York Edison Co., New York, N. Y.
Wells, L. J., Safety Electric Products Co., Los Angeles, Calif.
Wells, W. H., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Welsh, T. H., Western Power Co., of Canada, Stave Falls, B. C.
Wentworth, W. O., Columbia University, New York, N. Y.
Wentz, J. F., Western Electric Co , Inc., New York, N Y.
Wheeler, B., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
White, B. E., (Member), Utica Gas & Electric Co., Utica, N. Y.
Whiteman, C. F., Cleveland Electric Ill. Co., Cleveland, Ohio
Whittlesey, W. A., Pittsfield Electric Co., Pittsfield, Mass.
Wiegand, H. H. C., Brooklyn Polytechnic Institute, Brooklyn, N. Y.
Wildermann, O., Western Electric Co., Inc., New York, N. Y.
Willard, H. E., 4722, 8th Ave., Seattle, Wash.
Willits, E. J., Bureau of Power & Light, Los Angeles, Calif.
Willoughby, F., Jr., New York Edison Co., New York, N. Y.
Wills, D. C., Western Electric Co., Inc., Chicago, Ill.
Wing, H. R., Federal Electric Co., Chicago, Ill.
Wolf, D. J., Consumers Power Co., Jackson, Mich.
Wolf, E., Submarine Signal Corp., Boston, Mass.
Woods, C. R., Kansas City Power & Light Co., Kansas City, Mo.
Woods, D. W., Jr., Bel. Tel. Co. of Pa., Philadelphia, Pa.
Woods, S. K., Brooklyn Edison Co., Brooklyn, N. Y.

Wu, T. M., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Wurthman, A. D., American Tel. & Tel. Co., New York, N. Y.
Yard, A. S., American Gas & Electric Co., New York, N. Y.
Yonezawa, Y., Mitsui & Co., New York, N. Y.
Young, N. J., (Member), Lockport Lt. Ht. & Pr. Co., Lockport, N. Y.
Young, W. A., University of Illinois, Urbana, Ill.
Zahour, R. L., Westinghouse Lamp Co., New York, N. Y.
Zehr, G. A., The Niagara Falls Power Co., Niagara Falls, N. Y.
Zueloe, F. W., General Electric Co., Schenectady, N. Y.
Total 433.

Foreign

Baker, R. D., Wellington Corp., Wellington, N. Z.
Caldwell, A. C. A., Public Works Dept., Wellington, N. Z.
Davidson-Arnott, T., (Member), Davidson-Arnott & Co., Ltd., Port of Spain, Trinidad, B. W. I.
Kau, P. F., Pearl Harbor Naval Station, Honolulu, T. H.
Vicary, L. C., Springs-Ellesmere Power Board, Leeston, N. Z.
Total 5.

STUDENTS ENROLLED DECEMBER 14, 1923

18024 Handy, Francis E., University of Maine.
18025 Murray, John D., Queen's University
18026 Frederick, John R., Armour Inst. of Tech.
18027 Geyer, Helmut W., Mass. Inst. of Tech.
18028 Wilfley, Vernon B., State Univ. of New Mexico
18029 Bartholomaeus, John, Johns Hopkins Univ.
18030 Mackenzie, Murdo J., Bucknell University
18031 Jacocks, Thomas B., Jr., University of North Carolina
18032 Hersam, Hubert M., Univ. of Notre Dame
18033 Wilcox, Chester A., Stanford University
18034 DeBoeck, Pedro, Stanford University
18035 Middleton, Roy A., University of Missouri
18036 Houser, John W., University of Missouri
18037 Longmire, Harry E., Univ. of Missouri
18038 Young, Lawrence A., Univ. of Missouri
18039 Strieder, Henry P., University of Missouri
18040 Brittingham, Louis W., Univ. of Missouri
18041 Hodge, Dryden, University of Missouri
18042 Campbell, Walter H., University of Utah
18043 Newell, David M., Northeastern University
18044 Mitkewich, W., Yale University
18045 Rhoads, Mark, Yale University
18046 Burns, John J., Yale University
18047 Chinn, Burkitt C., Yale University
18048 Wenzinger, Carl J., Swarthmore College
18049 Tecklenburg, Herbert C., Brooklyn Polytechnic Institute
18050 Dolawitz, Nathan N., Brooklyn Poly. Inst.
18051 Berman, Simon L., Brooklyn Poly. Inst.
18052 Pledge, John A., Johns Hopkins University
18053 Martin, Joseph T., Mass. Inst. of Tech.
18054 Hyatt, Martin J., Cooper Union
18055 Henderson, Roy A., University of Iowa
18056 Bowen, Harland W., University of Iowa
18057 Sloan, Clarence O., University of Iowa
18058 Blythe, Everett G., University of Iowa
18059 Panth, Bhola D., University of Iowa
18060 Spina, Rocco L., University of Nevada
18061 Mahley, Fred W., Syracuse University
18062 Westbrook, John L., State College of Wash.
18063 Congleton, Ray T., Univ. of Cincinnati
18064 Winter, John E., University of Cincinnati
18065 MacDonald, Donald J., Cooper Union
18066 Decker, Perl A., University of Nevada
18067 Koch, Charles J., Mass. Inst. of Tech.
18068 Russell, Chester, Jr., State University of New Mexico
18069 Estill, Junius F., Jr., Texas A. & M. Coll.
18070 Seidel, Theodore B., Penn. State College
18071 Wolfe, Karl M., West Virginia University
18072 Mountain, William W., West Virginia University
18073 Roush, Dallas S. T., West Virginia Univ.
18074 Hill, Pierre F., West Virginia University
18075 Worden, Leo F., West Virginia University
18076 Christensen, Arthur L., Univ. of Minnesota
18077 Albrecht, Ernest G., Univ. of Minnesota
18078 Albrecht, Karl J., University of Minnesota
18079 Allen, Guy L., University of Minnesota
18080 Anderson, Matthew A., Univ. of Minnesota
18081 Benson, Ikel C., University of Minnesota
18082 Bordeau, Sanford P., Univ. of Minnesota
18083 Brossard, Henry F., Univ. of Minnesota
18084 Brown, Winfield P., Univ. of Minnesota
18085 Cass, Hoyt R., University of Minnesota
18086 Cassidy, Walter J., Univ. of Minnesota
18087 Cosandey, Charles J., Univ. of Minnesota
18088 Edwards, Richard G., Univ. of Minnesota
18089 Ellis, Carl E., University of Minnesota
18090 Franzen, Roy O., University of Minnesota
18091 Gaalaas, George, University of Minnesota
18092 Getten, Everett Z., Univ. of Minnesota
18093 Haberman, Ralph H., Univ. of Minn.
18094 Hammer, Harold E., University of Minn.
18095 Hanft, Hugo H., University of Minnesota
18096 Holmes, Raymond H., Univ. of Minnesota
18097 Kee, Harold C., University of Minnesota
18098 Keller, Raymond W., Univ. of Minnesota
18099 Koch, Winfield R., University of Minnesota
18100 Larsen, Einar H., Univ. of Minnesota
18101 Lewis, Berkeley R., Univ. of Minnesota
18102 Lund, Jeffery L., University of Minnesota
18103 Lyberg, Verele C., University of Minnesota
18104 Malmgren, R. V., University of Minnesota
18105 Maltby, Harold F., Univ. of Minnesota
18106 McCully, James P., Univ. of Minnesota
18107 McEwen, A. Dean, Univ. of Minnesota
18108 Morton, Lysle W., Univ. of Minnesota
18109 Nelson, Carl C., University of Minnesota
18110 Nelson, Clarence H., Univ. of Minnesota
18111 Nierling, Grant C., Univ. of Minnesota
18112 Parsons, Sidney A., Univ. of Minnesota
18113 Peterson, Lewis E., Univ. of Minnesota
18114 Reed, Henry R., University of Minnesota
18115 Robertson, Kenefick, Univ. of Minnesota
18116 Robinson, Lawrence T., Univ. of Minn.
18117 Salo, William J., Jr., Univ. of Minnesota
18118 Shavor, George J., University of Minnesota
18119 Steinert, Emil F., University of Minnesota
18120 Thyberg Clarence W., Univ. of Minnesota
18121 Tunell, Clement R., Univ. of Minnesota
18122 Untinen, August L., Univ. of Minnesota
18123 Weyer, Herbert R., Univ. of Minnesota
18124 Wieland, Willard W., Univ. of Minnesota
18125 Winslow, Harry J., Univ. of Minnesota
18126 Wurzbach, H. Allen, Univ. of Minnesota
18127 Schneckloth, Harry H., Univ. of Minnesota
18128 Anderson, Arthur P., Univ. of Minnesota
18129 Boe, Lester L., University of Minnesota
18130 Childs, Norris P., University of Minnesota
18131 Graf, Alois W., University of Minnesota
18132 Jacobson, Arthur C., Univ. of Minnesota
18133 Juran, Joseph M., Univ. of Minnesota
18134 Richardson, Philip E., Univ. of Minnesota
18135 Solomonson, Lawrence D., University of Minnesota
18136 Laurence, Rodolphe G., Cooper Union
18137 Peterson, Arthur C., State College of Wash.
18138 Neely, Thomas H., Cooper Union
18139 Schacht, Delbert H., Univ. of Wisconsin
18140 Alberti, John N., Worcester Poly. Institute
18141 Seecamp, John F., Univ. of Washington
18142 Cookingham, Merritt G., Univ. of Wash.
18143 Welsh, William J., Univ. of Washington
18144 Johnson, Frederick A., Univ. of Wash.
18145 Treadwell, Milton S., George Wash. Univ.
18146 Roeser, William F., George Wash. Univ.
18147 La Rue, Wilton W., George Wash. Univ.
18148 Nesbett, John G., Cornell University
18149 Stricklett, Schubert A., Case School of Applied Science
18150 Ashley, Raymond L., Johns Hopkins Univ.
18151 Fairbrother, George, University of Nevada
18152 Amezaga, Miguel F., Mass. Inst. of Tech.
18153 Powell, John B., Lafayette College
18154 Gilpin, Fred P., University of Illinois
18155 Mueller, Walter E., University of Illinois
18156 Johnson, Royce E., Univ. of Wisconsin
18157 Masters, D. B., University of Wisconsin
18158 Saunders, Mervin L., University of Utah
18159 Eastman, Elmer D., University of Utah
18160 Spenner, Frank, University of Iowa
18161 Goodwin, Robert C., Purdue University
18162 Hardsog, E. Floyd, Purdue University
18163 Dinius, Kenneth E., Purdue University
18164 Wilkins, Raymond A., Purdue University
18165 Dome, Robert B., Purdue University
18166 Dresser, John D., Purdue University
18167 Beedle, Paul W., University of Illinois
18168 Ballard, Randall C., University of Illinois
18169 Knouf, Ralph J., Iowa State College
18170 Larsen, Christian L., University of Illinois
18171 Betts, Robert A., Alabama Poly. Institute
18172 Cresson, George V., Univ. of Pennsylvania
18173 Terkelson, G. Alfred, Univ. of Pennsylvania
18174 de Zamacona, Louis, Univ. of Pennsylvania
18175 Kinckiner, Ralph A., Univ. of Pennsylvania
18176 Martin, Samuel, Jr., Univ. of Pennsylvania
18177 McKay, John L., Jr., Univ. of Pennsylvania
18178 Henderson, Francis L., Univ. of Penn.
18179 Ortlieb, Otto P., Univ. of Pennsylvania
18180 Brown, Elbert C., Mass. Institute of Tech.
18181 Cook, Witter T., Mass. Inst. of Technology
18182 Collins, Walter, J., University of Nebraska
18183 Eiche, Louis B., University of Nebraska
18184 Haycock, Obed C., University of Utah
18185 Parker, Ray H., University of Nevada
18186 Imokawa, John K., Stanford University
18187 Rush, Philip E., Ohio State University
18188 Herrick, George H., Ohio State University
18189 Wasson, Harold, Ohio State University
18190 Rush, Samuel E., Ohio State University
18191 Nelson, Harold E., Ohio State University
18192 McCurley, James C., Ohio State University
18193 McCann, Thomas A., 3rd, Ohio State Univ.
18194 Loomis, Robert O., Ohio State University
18195 Winegardner, John C., Ohio State Univ.
18196 Harsh, Milo C., Ohio State University
18197 Hoddy, Gerald L., Ohio State University
18198 Murdock, Raymond R., Ohio State Univ.
18199 Madden, Robert Emmett, Ohio State Univ.
18200 Hartzell, Herman L., Ohio State Univ.
18201 Hunt, Frederick V., Ohio State University
18202 Egry, Russel P., Ohio State University
18203 Comly, James M., Ohio State University
18204 Stanton, Harold W., University of Iowa
18205 Adamson, Eugene R., Univ. of California
18206 Armer, Austin A., University of California
18207 Auser, Jack M., University of California
18208 Barker, Marshall B., University of Calif.
18209 Bolinger, John C., University of California
18210 Buckle, Raymond J., Univ. of California
18211 Cameron, D. G., University of California
18212 Carr, Alden W., University of California
18213 Chan, F. J., University of California
18214 Chan, Leonard O., University of California
18215 Conkling, Donald W., University of Calif.
18216 Dixon, Evander S., Univ. of California
18217 Doyle, Bernard D., University of California
18218 Ford, Robert O., University of California
18219 Fullmer, G. Elmo, Univ. of California
18220 Gardiner, Paul C., University of California
18221 Gerlach, Leonard J., Univ. of California
18222 Haglund, Carl E., University of California
18223 Hammond, Richard A., Univ. of California
18224 Hildebrand, E. H., Univ. of California
18225 Hockenbeamer, Embra F., Univ. of Calif.
18226 Hudd, Stanley M., University of California
18227 Hurley, Raymond A., Univ. of California
18228 Hurt, Fred E., University of California
18229 Jang, Yen, University of California
18230 Kempf, Rupert E., University of California
18231 Kennedy, Clarence M., Univ. of California
18232 Kenney, James T., University of California
18233 Labadie, Louis R., University of California
18234 Leask, George D., University of California
18235 Lusk, Hilton F., University of California
18236 McCrystle, William J., Univ. of California
18237 Weyer, Betram W., Univ. of California
18238 Michael, Sydney M., University of Calif.
18239 Moffat, Charles E., University of California
18240 Nisja, Roy A., University of California
18241 Noe, Everett V., University of California
18242 Nutting, D. C., University of California
18243 Nutting, Marcus, University of California
18244 Olsen, Harold A., University of California
18245 Peterson, Clarence L., University of Calif.

18246 Rothganger, Frank G., Univ. of California
18247 Rusk, Daniel O., University of California
18248 Samuels, Raemon C., Univ. of California
18249 Schaefer, Anton H., Univ. of California
18250 Schmidt, Eugene A., Univ. of California
18251 Shelly, Joseph J., Univ. of California
18252 Spaulding, John N., Univ. of California
18253 Terry, Ralph V., University of California
18254 Towers, Richard A., Univ. of California
18255 Tung, Chi-Tai, University of California
18256 Turnquist, Karl E., Univ. of California
18257 Vendley, Clarence E., Univ. of California
18258 Weiss, Burrage, University of California
18259 Wilson, Irving S., University of California
18260 Rotermund, M. A., University of California
18261 Wahlund, Carl B., University of Nevada
18262 Pressell, Willis R., University of Nevada
18263 Norling, Bert S., Washington State College
18264 Hyatt, Lloyd W., John Hopkins Univ.
18265 Wetherill, Lynn, Mass. Inst. of Technology
18266 Stockwell, Laurence F., Northeastern Univ.
18267 Kinsella, Ennis, University of Nevada
18268 Wendell, Edward N., Mass. Inst. of Tech.
18269 Olson, Arthur J., Mass. Inst. of Technology
18270 Langsam, Harry, Univ. of Pennsylvania
18271 McLachlan, Willard J., Wash. State Coll.
18272 Young, Kenneth C., Northeastern Univ.
18273 Murphy, Eloy J., Brown University
18274 Orton, Donald L., Ohio Northern Univ.
18275 Buckley, Clifton L., Bucknell University
18276 Quinn, Robert P., Mass. Inst. of Tech.
18277 Brookes, Albert S., Mass. Inst. of Tech.
18278 Shower, Edmund G., Johns Hopkins Univ.
18279 Troccoli, Frank A., Northeastern Univ.
18280 Lindstrom, Einar, University of Colorado
18281 Reed, Cecil B., University of Colorado
18282 Eddy, Raymond W., Univ. of Colorado
18283 Kliewer, Harry, University of Colorado
18284 Davis, Chester, University of Colorado
18285 Hubbard, Henry H., Univ. of Michigan
18286 Dornbos, Leo J., University of Michigan
18287 Curl, Herbert C., University of Michigan
18288 Kratz, Frederick S., University of Michigan
18289 Brisbin, Merton M., Univ. of Michigan
18290 Gruncharoff, Anton J., Univ. of Michigan
18291 Hathaway, Leonard B., Rhode Island State College
18292 Pike, Charles A., Rhode Island State Coll.
18293 Wolf, Alexander, Univ. of Pennsylvania
18294 Norman, George H. C., Univ. of British Columbia
18295 Barrett, Charles S., Univ. of South Dakota
18296 Clarke, Eral N., University of South Dakota
18297 Gilbertson, Alph B., Univ. of South Dakota
18298 Richards F. Ira., Univ. of South Dakota
18299 Thrush, George H., Jr., Gettysburg College
18300 Hicks, Charles D., University of Nevada
18301 Harris, Everett W., University of Nevada
18302 Moyer, Harry E., University of Nebraska
18303 Carr, Benjamin P., Michigan Agricultural College
18304 Moseman, Paul W., University of Nebraska
18305 Lawton, Sidney M., Univ. of South Dakota
18306 Mercereau, James T., Calif. Inst. of Tech.
18307 Schumaker, Halsey R., Calif. Inst. of Tech.
18308 Reed, Jack Switzer, Calif. Inst. of Tech.
18309 Bryant, Walter L., Jr., Calif. Inst. of Tech.
18310 Krouser, James C., Calif. Inst. of Tech.
18311 Schueler, Alfred E., Calif. Inst. of Tech.
18312 McClung, Frederick J., Calif. Inst. of Tech.
18313 Hall, Lawrence W., Calif. Inst. of Tech.
18314 Lovitt, Lawrence E., Univ. of New Mexico
18315 Garman, George W., Univ. of Washington
18316 Covington, Duane M., Univ. of Wash.
18317 Robinson, H. Gerald, Univ. of Washington
18318 Dawson, Lee R., University of Washington
18319 Honour, J. Welsby, Jr., Georgia School of Technology
18320 Hubbard, George A., Georgia Sch. of Tech.
18321 Kelly, Fred G.., Jr., Georgia Sch. of Tech.
18322 Parkis, Donald M., Georgia Sch. of Tech.
18323 Marlowe, John F., Georgia Sch. of Tech.
18324 Pudney, Lewis E., Georgia School of Tech.
18325 Finkelstin, Joe, Georgia School of Tech.
18326 Cooper, Robert L., Georgia Sch. of Tech.
18327 Westbrook, William L., Georgia School of Technology
18328 Johnson, Cecil P., Georgia School of Tech.
18329 O'Shee, Patrick C., Georgia Sch. of Tech.
18330 L'Heureux, Luke J., Georgia Sch. of Tech.
18331 Stevens, Walter C., Georgia Sch. of Tech.
18332 Bald, George H., Jr., Johns Hopkins Univ.
18333 Remy, Walter A., Columbia University
18334 Preisman, Albert, Columbia University
18335 Fouse, Ralph W., Pennsylvania State Coll.
18336 Pierce, Melvin G., Northeastern University
18337 Wells, Jos. A., Armour Institute of Tech.
18338 Schwarz, Edwin, Armour Inst. of Tech.
18339 Lierley, John T., University of Utah
18340 Magee, Charles F., Villanova College
Total 317

Officers A. I. E. E. 1923-1924

PRESIDENT

(Term expires July 31, 1924)

HARRIS J. RYAN

JUNIOR PAST-PRESIDENTS

(Term expires July 31, 1924)
WILLIAM McCLELLAN

(Term expires July 31, 1925)
FRANK B. JEWETT

VICE-PRESIDENTS

(Terms expire July 31, 1924)
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R. F. SCHUCHARDT (District No. 5)
H. T. PLUMB (District No. 9)
G. FACCIOLI (District No. 1)
H. W. EALES (District No. 7)

(Terms expire July 31, 1925)
J. E. MACDONALD (District No. 8)
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(Terms expire July 31, 1924)
HAROLD B. SMITH
JAMES F. LINCOLN
E. B. CRAFT

(Terms expire July 31, 1925)
R. B. WILLIAMSON
A. G. PIERCE
HARLAN A. PRATT

(Terms expire July 31, 1926)
H. M. HOBART
ERNEST LUNN
G. L. KNIGHT

(Terms expire July 31, 1927)
WILLIAM M. McCONAHEY
W. K. VANDERPOEL
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TREASURER **SECRETARY**

(Terms expire July 31, 1924)

GEORGE A. HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY
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*Norvin Green, 1884-5-6.
*Franklin L. Pope, 1886-7.
T. Commerford Martin, 1887-8.
Edward Weston, 1888-9.
Elihu Thomson, 1889-90
*William A. Anthony, 1890-91.
*Alexander Graham Bell, 1891-2.
Frank Julian Sprague, 1892-3.
*Edwin J. Houston, 1893-4-5.
*Louis Duncan, 1895-6-7.
*Francis Bacon Crocker, 1897-8.
A. E. Kennelly, 1898-1900.
Carl Hering, 1900-1.
*Charles P. Steinmetz, 1901-2.
Charles F. Scott, 1902-3.
Bion J. Arnold, 1903-4.
John W. Lieb, 1904-5.
*Schuyler Skaats Wheeler, 1905-6.
*Samuel Sheldon, 1906-7.
*Henry G. Stott, 1907-8.
Louis A. Ferguson, 1908-9.
Lewis B. Stillwell, 1909-10.
Dugald C. Jackson, 1910-11.
Gano Dunn, 1911-12.
Ralph D. Mershon, 1912-13.
C. O. Mailloux, 1913-14.
Paul M. Lincoln, 1914-15.
John J. Carty, 1915-16.
H. W. Buck, 1916-17.
E. W. Rice, Jr., 1917-18.
Comfort A. Adams, 1918-19.
Calvert Townley, 1919-20.
A. W. Berresford, 1920-21.
William McClellan, 1921-22.
Frank B. Jewett, 1922-23.

*Deceased.

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Charles le Maistre, 28 Victoria St., London, S. W., England.
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H. P. Gibbs, Tata Sons Ltd., Navsari Building, Fort Bombay, India.
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G. L. Knight, F. D. Newbury, C. E. Skinner.
Harold Pender,

Ex-Officio

Chairmen of Working Committees of Standards Committee
Chairmen of A. I. E. E. delegations on other standardizing bodies.

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(Term expires July 31, 1924)
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(Term expires July 31, 1925)
H. M. Byllesby, D. E. Drake, W. L. R. Emmet.

(Term expires July 31, 1926)
B. A. Behrend, John H. Finney, C. S. Ruffner.

(Term expires July 31, 1927)
Gano Dunn, F. A. Scheffler, W. R. Whitney.

(Term expires July 31, 1928)
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Mailed to interested readers by issuing companies

Pulverized Coal Equipment.—Bulletin 900, 32 pp. Describes apparatus for preparing, conveying, feeding and burning pulverized coal. Fuller-Lehigh Company, Fullerton, Pa.

Engineering Achievements in 1923.—Bulletin, 10 pp., describing the accomplishments of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Mechanical Stoker.—Bulletin, 4 pp., describing the new Frederick Stoker, multiple retort, underfeed. Combustion Engineering Corporation, Broad St., New York.

Pole Line Insulators.—Hand book, 24 pp. Describes a complete range of porcelain insulators for lines up to 45,000 volts. Illinois Electric Porcelain Company, Macomb, Ill.

Railway Motors. Specifications Nos. 557 and 562. Describes railway motors of 140 and 100 hp. hourly ratings. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Meters.—Leaflet, Illustrates the complete line of Sangamo meters. Sangamo Electric Company, Springfield, Ill.

Developments of the Electrical Industry in 1923. A review of electrical developments during the past year. General Electric Co., Schenectady, N. Y.

Vitrohm Speed Regulator.—Bulletin 4 pp. Designed for use with all types of constant torque, d-c. motors up to 1/8 hp., 115 to 230 volts, and up to 1/2 hp., variable torque. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Flexible Couplings. Bulletin 37, 32 pp. A comprehensive description of Francke Flexible Couplings for direct-connected machines, illustrating numerous applications. Smith & Serrell, 20 Halsey Street, Newark, N. J.

Micarta. Booklet, 24 pp. "A Material of Endless Possibilities," describing Micarta and the uses to which it has been put. Some of these are bushings, cord terminals, disks, fan blades, gears, insulators, radio panels, telephone apparatus and switchboards. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Vitreosil. Booklet, 16 pp. describing fused quartz or silica, marketed under the trade name of Vitreosil. This material is used as an electrical insulator, among other purposes, and has a higher melting point than either glass or porcelain. The Thermal Syndicate, Ltd., 350 Madison Ave., New York.

The Audiphone. Bulletin, 12 pp. A special vacuum tube amplifying equipment used as an aid to hearing. This device, which is made in three different types, employs very sensitive transmitters to convert the original sound waves into electrical waves. The vacuum tube amplifiers receive the electrical waves and intensify them without perceptible distortion, and these waves are in turn converted into mechanical energy through telephone receivers and give a faithful reproduction of the original sounds. Western Electric Company, 9 East 41st Street, New York.

NOTES OF THE INDUSTRY

A Four-Story Oil Circuit Breaker.—A switch built on the plan of a skyscraper in order to conserve ground area is one of the recent developments of the General Electric Company. An equipment of 28,000 volt, triple pole, oil circuit breakers which, including control and operating mechanism, occupy a space just five feet square and rise 58 feet into the air, is now being built for the Hudson Avenue generating station of the Brooklyn Edison Company.

The departure from the regular order of design lies in the arrangement and control, rather than in the breaker units, which are of the standard F K-130 type. The units are placed one above the other, one phase to a floor, with the operating mechanism on the uppermost floor, giving rise to the designation of "four-story" oil circuit breaker.

Recording Instrument. A new portable recording instrument known as Type R has recently been developed by the Westinghouse Elec. & Mfg. Co., East Pittsburgh. It is made for applications where records as accurate and reliable as those obtained with large switchboard instruments are necessary. Such applications include analysis of motor operation, typical consumption, curves of large industrial consumers, and records of power distribution. The instrument is an adaptation of the switchboard recording instrument, with the element as a whole mounted in a portable carrying case. An electric self winding clock is used for speeds up to 24 inches per hour. For slower speeds, up to four inches per hour, a hand wound clock can be used. A-c. ammeters, a-c. and d-c. voltmeters, and single and polyphase wattmeters are made in these portable recording instruments.

Two New York Power Companies Tie-In.—The 25 and 60 cycle power systems of the New York Edison Company and the United Electric Light & Power Company were recently tied together at the Hell Gate station of the latter company. This tie-in was accomplished by means of a General Electric 35,000 kw. induction synchronous type frequency converter, establishing a record in frequency converter ties, representing a total of 727,000 kv-a. working in synchronism on the two systems.

The kilowatt capacity of this set is nearly three times that of the largest frequency converter previously built and marks a new epoch in the construction of horizontal shaft alternating current machines. The induction unit is the largest induction motor in the world and has a continuous rating of 37,000 kv-a. The synchronous generator, rated 25,000 kv-a. is larger than any horizontal shaft salient pole generator previously constructed. The installation also includes the largest air blast transformer in the world.

Record Cable Output.—If it were possible to string worlds like beads on a necklace, fifty-two planets like the earth could be strung on the length of wire put into lead-covered telephone cable by the Chicago Works of the Western Electric Company during November. And the average weekly production for the month would be long enough to run through the world from pole to pole thirteen times.

These comparisons emphasize the tremendous output of cable represented by the new high record achieved in November. In four weeks the Chicago factory almost surpassed the best previous record of a five-week month. The weekly average production for November was 565,795,000 feet of conductor wire. The total production for the month was 2,263,180,000 feet of conductor wire.

Output is stated in "conductor feet" because of the fact that different sizes of cable are made up of a different number of pairs of wire. The conductor foot is a term representing the amount of wire going into cable of all sizes, and is a standard unit of measurement for purposes of comparison.

The continuous development of the Bell Telephone System and the resulting demand for telephone equipment is responsible for the great production of cable. In response to this pressing demand the Chicago Works of the Western Electric has repeatedly established new records of manufacture during the past years.

Charles Frankel, President of the Frankel Connector Company, Inc., New York, died December 18th. He was an active member of the Electrical Board of Trade and a member of the National Electric Light Association, and during the past few years he took a very active part in all electrical matters.